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REVIEW

Essential Oils of Anatolian Apiaceae - A Profile¶

K. Hüsnü Can Baser[1,2] and Neş'e Kırımer[1]

[1] Anadolu University, Faculty of Pharmacy, Department of Pharmacognosy, 26470 Eskişehir, Turkey.

[2] King Saud University, College of Science, Department of Botany and Microbiology, Riyadh, Saudi Arabia

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Abstract

The family Apiaceae is represented in Turkey by 101 genera belonging to 485 species included in 511 taxa comprising 181 endemics, 7 genera being monotypic. The ratio of species endemism in the family is 37.3 %.
We have screened the literature for Apiaceae taxa studied for their essential oils and compiled the data in order to get a clear aromatic profile of the family. It has become obvious that our group has been very active in this matter. We have so far investigated taxa belonging to 58 genera including the monotypic genera *Ekimia bornmuelleri, Olymposciadium caespitosum* and published on their essential oil yields and compositions.
Apiaceae is an interesting family comprising many aromatic taxa including commercialized Herbas and spices such as anis, fennel, cumin, caraway, coriander, chervil, parsley, carrot, asa foetida, galbanum, etc. Some are rich in essential oils. The most interesting feature of the family is that many of its members have high chemical diversity containing different aromatic chemicals in different organs. Therefore, it is advisable to study all parts (e.g., fruit, flower, stem, leaf and root) of an Apiaceae plant separately in order to get a complete chemical profile of that taxon.

Apiaceae genera of Turkey studied so far for their essential oils are as follows:
Actinolema, Ammi, Anethum, Angelica, Anthriscus, Apium, Artedia, Bifora, Bilacunaria, Bunium, Bupleurum, Cachrys, Chaerophyllum, Cnidium, Coriandrum, Crithmum, Cuminum, Cymbocarpum, Daucus, Diplotaenia, Echinophora, Ekimia, Eryngium, Ferula, Ferulago, Foeniculum, Fuernrohria, Glaucosciadium, Grammosciadium, Heptaptera, Heracleum, Hippomaranthum, Johrenia, Kundmannia, Lagoecia, Laser, Laserpitium, Malabaila, Myrrhoides, Neocryptodiscus, Olymposciadium, Pastinaca, Petroselinum, Peucedanum, Physocaulis, Pimpinella, Prangos, Rhabdosciadium, Scaligeria, Scandix, Seseli, Smyrnium, Szovitsia, Tordylium, Trachyspermum, Trinia, Xanthogalum, Zosima.

KEYWORDS: Review, Apiaceae, essential oil, Turkey

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Introduction

The family Apiaceae is represented in Turkey by 101 genera belonging to 485 species included in 511 taxa comprising 181 endemics (= E). Endemic monotypic genera include *Crenosciadium, Microsciadium, Olymposciadium, Muretia, Froriepia, Stenotaenia* and *Ekimia*. Other endemic genera are *Rhabdosciadium* (3 spp.) and *Kundmannia* (2 spp.) (Davis, 1972; 1988; Duman H. and Watson, 1999; Ozhatay et al. 1994; 1999; 2009; Guner et al. 2000, Duran, 2014)

Apiaceae species are rich in essential oils. They may contain essential oils in fruits, flowers, leaves, roots and stem. Chemical diversity is so varied that essential oil components in underground and aboveground parts may vary significantly. Fruit type in Apiaceae is schizocarp meaning that seed is fused with the fruit in such a way that it is impossible to separate them from eachother. This is the reason why Apiaceae fruits are often called seeds such as aniseeds, cumin seeds, coriander seeds, fennel seeds, etc. Fruit essential oils in Apiaceae

are contained in oil ducts called *vittae*. Such subcutaneus oils give higher yields when crushed before distillation. If whole fruits are distilled, oxygenated components, which are generally less volatile but more water soluble, appear earlier in the distillate. This can be explained by the hydrodiffusion phenomenon. More water soluble components in oil ducts diffuse to the surface of the fruit and are carried away by the passing steam. More volatile but less water soluble hydrocarbons are eluted later. Hydrophobics are released by crushing the material to break the oil ducts prior to distillation. Heating of the material facilitates the removal of hydrocarbons. Crushing the fruits prior to distillation facilitates distillation of hydrocarbons as well as other components.

Several Apiaceae species are ingredients of foods and therefore their large scale cultivation is required. Surplus of domestic use is generally exported. Major Apiaceae crops cultivated in Turkey are aniseed (*Pimpinella anisum*), cumin (*Cuminum cyminum*), coriander (*Coriandrum sativum*), fennel (*Foeniculum vulgare*). Some lesser crops cultivated or used in Turkey include celery (*Apium graveolens*), dill (*Anethum graveolens*), parsley (*Petroselinum sativum*) and laser (*Laser trilobum*).

In 2013, Turkey exported 7.942 tons of cumin fruits for a return of USD 20.5 million. Exports of aniseeds amounted to 1.944 tons for a return of USD 7.9 million. 15 years ago it was 4.000 tons. When Turkish State Monopolies (TEKEL) used to purchase 7000 tons annually for the production of an alcoholic drink called RAKI (Baser, 1997b). Since then, TEKEL has been privatized and the state monopoly over RAKI has been lifted. Therefore, most of the aniseed production is consumed by the domestic Raki producers and only a small surplus is exported. Export figures of fennel and juniper are collectively cited under the same HS (Harmonised system) code in export statistics. Their combined exports amounted to 894.292 kg in 2011 for a return of USD 2.5 million. Coriander exports of Turkey in 2013 were 229 tons for USD 566.088 (Table 1).

Table 1. Export of Some Apiaceae Crops of Turkey

		1997	**2013**
Aniseed	kg	3.907.492	1.944.227
	$	8.891.921	7.889.501
	$/kg	2.28	4.05
Cumin	kg	12.927.275	7.941.924
	$	19.489.209	20.574.613
	$/kg	1.51	2.59
Fennel / Juniper fruit	kg	1.699.129	894.292*
	$	1.873.348	2.500.000*
	$/kg	1.10	1.33*
Coriander	kg		228.596
	$		566.088
	$/kg		2.48

**2011 figures*

Technical Information

1. Unless stated otherwise, all the oils were obtained by water distillation using a laboratory-scale Clevenger apparatus.
2. For micro-distillation, either an Eppendorf MicroDistiller or a Likens-Nickerson Simultaneous Distillation-Extraction apparatus were used.
3. Unless stated otherwise, all plant materials were ground prior to distillation.
4. For Gas Chromatographic / Mass Spectrometric Analysis, a Shimadzu QP2000A, QP5050, a Hewlett-Packard G1800A MSD and Agilent 5975GCMSD systems were used.
5. For chiral separations, the Multi-Dimensional Gas Chromatography/Mass Spectrometry (MDGC/MS) system used consisted of two HP-GC6890 gas chromatographs + HP-MSD + Gerstel MCS system.

Apiaceae Oils of Turkey

CUMIN SEED OIL (*Cuminum cyminum* L.)

Cumin (Kimyon in Turkish) is an annual plant cultivated for its use as condiment and as an ingredient of sucuk (spicy meaty Turkish sausages).

15 essential oil samples from Turkey and four from abroad were subjected to analysis and the results are summarised in Table 2 (Baser et al., 1992). The following generalities can be drawn from the results.

1. *p*-Mentha-1,4-dien-7-al (γ-terpinen-7-al) predominates over the other components in lab-distilled oils.
2. Total aldehydes content in lab-distilled oils varies between 61-78% while in commercial oils it falls between 29-46%.
3. Monoterpene hydrocarbons predominate over the aldehydes in commercial oils (32-66%)
4. In commercial Turkish and Egyptian oils cuminaldehyde is the main constituent while γ-terpinene is the main component in Indian oils.

5. *p*-Mentha-1,4-dien-7-al (γ-terpinen-7-al) is the main component in fresh seeds. It is easily oxidised to cuminaldehyde in pre-ground seeds during storage or during the heat treatment associated with distillation of the commercial oil.

Table 2. Cumin seed oil

	Water distilled		**Steam distilled**		**Commercial**		
	whole	**ground**	**whole**	**ground**	**Turkish**	**Egyptian**	**Indian**
Yield (%)	1.2-3.2	1.4-1.6	1.2	1.2-1.7			
p-mentha-1,4-dien-7-al (α-terpinen-7-al)	31-49	25-38	41	28-32	2-8	6	2-3
cuminaldehyde	19-25	21-25	26	21-27	22-40	20	20-31
p-mentha-1,3-dien-7-al (α-terpinen-7-al)	4-12	4-12	12	6-11	8-13	9	7-11
p-cymene	5-9	6	5	6	6-9	9	14-18
γ-terpinene	7-11	14-15	7	14-16	11-23	18	29-32
β-pinene	3-7	7-8	3	6-9	8-16	10	4-13

We have also published on the hydrodistilled essential oils of unripe, ripe and fully ripe cumin fruits cultivated in Konya (Table 3).

Table 3. Cumin seed oils at different vegetative states (Kan et al, 2007)

Yield (%)	1.9	2.4	2.3
p-mentha-1,4-dien-7-al (= γ-terpinen-7-al)	16.9	13.9	16.0
cuminaldehyde	19.9	23.6	20.4
p-mentha-1,3-dien-7-al (= γ-terpinen-7-al)	14.1	17.5	11.4
p-cymene	7.7	9.6	11.6
γ-terpinene	10.3	11.5	13.6
α-phellandrene	8.5	4.1	5.4
β-pinene	8.7	7.4	9.0
Total aldehydes	**50.9**	**65.0**	**55.8**

Impact compounds of the cumin fruit oil are the three aldehydes. Their total percentages amounted to 50.9%, 65.0% and 55.8% in unripe, ripe and fully ripe fruits, resp. (Kan et al, 2007).

Another paper on the Turkish cumin seed oil reported only cuminaldehyde as 55% together with edulan (10%) and carotol (5%) without mention of other aldehydes and monoterpenes. Scientific value of this paper is questionable (Topal et al., 2008).

Our group has also determined the steam distillation process parameters of cumin seed oil using a 500 liter pilot plant. Optimum conditions for the best yield of oil were found as 0.5 mm particle size, 35 kg batch size, distillation rate 0.28 kg/ $kg^{-1}h^{-1}$, distillation time 3 h. Major components were found as cuminaldehyde 27.6%, γ-terpinene 17.3%, *p*-mentha-1,3-dien-7 al (γ-terpinen-7-al) 15.2%, β-pinene 10.2%, *p*-mentha-1,4-dien-7-al (γ-terpinen-7-al) 9.5% (Beis et al., 2000).

Bunium persicum (Boiss.) B.Fedtsch. (Umbelliferae) is also a native plant of Turkey with no reported use. However, the fruits of this species are used in place of cumin in Central Asia, Afghanistan and Pakistan. The analysis of fruits of *Bunium persicum* from Tajikistan revealed the presence of *p*-mentha-1,4-dien-7-al γ-terpinen-7-al) (29%), γ-terpinene (26%), β-pinene (16%) and cuminaldehyde (12%) as main constituents (Baser et al, 1997a).

LASER SEED OIL (*Laser trilobum* (L.) Borkh.)

Laser is an erect, glaucous perennial plant attaining a height of *ca.* 120 cm which grows wild scattered throughout Turkey except in the Southest region. Dried ripe fruits known as "kefe kimyonu" is traded and used as a spice in Turkey. The fruits have a cumin-like aroma with a resinous and spicy taste. A 2% decoction of the fruit is applied on the skin for acne.

Fruits from two localities in Turkey were subjected to different distillation modes and the oils were analysed. The results are summarised in Table 4 (Baser et al, 1993).

1. Perillaldehyde and limonene are the main constituents of Laser seed oil. Limonene is a monoterpene hydrocarbon. Perillaldehyde is an oxygenated monoterpene.
2. Due to reasons already explained, perillaldehyde is the main constituent in essential oil distilled from whole fruits. Crushed fruits or predistilled whole fruits yield oil rich in limonene.
3. Prolonged storage or heat treatment of Laser seeds produce an oil rich in perillaldehyde due to higher volatility of limonene.

Table 4. Laser seed oil

	Water distilled					**Steam distilled**	
	whole	**ground**	**cad**	**heated whole**	**heated ad**	**whole**	**ground**
Yield (%)	2-3	5-7	2-6	2	1	2	6
perillaldehyde	62-69	29-34	4-8	67	80	72	31
limonene	27-29	65-69	88-91	22	6	19	63

Cad: Crushed after distillation of the whole fruits.

Another recent study on laser fruits reported the yield of essential oil as 4.4-5.8% with limonene (41-72%) and perillaldehyde (4-33%) as main constituents (Parlatan et al, 2009).

APIACEAE OILS OF OTHER COMMERCIAL CROPS

Table 5 summarises the results of analysis of the essential oils of some commercial Apiaceae crops carried out at our laboratories.

Table 5. Main components of the essential oils of some commercial genera

Common name	**Latin name**	**% yield**	**Main components (%)**	**Ref.**
Carrot seed	*Daucus carota*	2.5	carotol 27	Baser, 2002
		0.83	carotol 67	Ozcan & Chalchat, 2007
Celery Herba	*Apium graveolens*	0.09	γ-terpinene 39	Baser, 2002
Chervil Herba	*Anthriscus cerefolium*	0.4	methyl chavicol 83, 1-allyl-2,4-di-methoxy benzene 15	Baser et al., 1998a
Coriander seed	*Coriandrum sativum*	0.4-2.0	(+)-linalool 89	Baser, 2002
Dill seed	*Anethum graveolens*	2.0-2.5	(+)-carvone 46-66	Kosar et al., 2005
Parsley seed	*Petroselinum sativum*	0.5	2,3,4,5-tetramethoxy allylbenzene 29	Baser, 2002
Angelica seed	*Angelica sylvestris* var. *sylvestris*	0.26	α-pinene 26, β-phellandrene 9, bornyl acetate 7, *p*-cresol 7	Ozek, T., et al., 2008

FENNEL OILS

Foeniculum vulgare var. *dulce* oil contains trans-anethole 80-95% as the main constituent with methyl chavicol (estragole) 3-16% as a minor component. In the oil of *F. vulgare* var. *piperitum* methyl chavicol 22-70% is the main constituent, fenchone 13-28% is second major component. *Trans*-anethole content is very low. *F. vulgare* var. *vulgare* oils are characterized by high *trans*-anethole content which is lower than that of *F. vulgare* var. *dulce*. *Trans*-anethole and methyl chavicol contents are similar in percentage values. Due to higher methyl chavicol contents this taxon is also called as bitter fennel.

Table 6. Fennel oils

Common name	**Latin name**	**Part**	**% yield**	**Main components (%)**	**Ref.**
Fennel seed, sweet	*Foeniculum vulgare* var. *vulgare*	Fruit	2.4-3.1	*trans*-anethole 65-88	Baser, 2002
		Fruit	3.1	*trans*-anethole 75, methyl chavicol 16	Cosge et al., 2008
		Fruit	6-12	*trans*-anethole 81-88, methyl chavicol 4-6, fenchone 1-3	Telci et al., 2009
	Foeniculum vulgare var. *dulce*	Fruit	3	*trans*-anethole 95, methyl chavicol 3	Cosge et al., 2008
Fennel seed, bitter	*Foeniculum vulgare* var. *piperitum*	Fruit	4.3-7.7	methyl chavicol 63-73, fenchone 18-28	Baser,2002
		Leaf	1-3	methyl chavicol 25-70, fenchone 8-15, limonene 2-10, fenchylacetate 2-14	Figueredo et al., 2011
		Root	0.17	methyl chavicol 59, fenchone 12, fenchylacetate 3	Özcan & Chalchat 2010
		Stem	0.87	methyl chavicol 61, fenchone 25	Özcan & Chalchat 2010
Florence fennel, finocchio	*Foeniculum vulgare* var. *azoricum*	Fruit		*trans*-anethole 59-72, limonene 8-11, apiole *tr*-9	Cetin et al, 2010

CORIANDER OIL

Coriander (*Coriandrum sativum*) is a cultivated crop whose fresh leaves and fruits are used as condiment and as a source of essential oil. Fruit oil is a rich source of the rare (+)-linalool and therefore important as a perfumery ingredient. Fresh leaves, rich in aliphatic aldehydes such as (*E*)-2-decenal, are added to soups and salads due to its pungent taste.

Table 7. Coriander oils

Plant name	**Part**	**% yield**	**Main components %**	**Ref.**
Coriandrum sativum	Fruit	0.3-1.2	linalool (16) 72-83	Kiralan et al., 2009; Sampson et al., 2005; Koşar et al 2005; Yıldırım & Gok, 2012.
C. sativum var. *vulgare*	Fruit	0.2-0.4	linalool 30-65	Telci et al., 2006a; 2006b.
C. sativum var. *macrocarpum*	Fruit		linalool 79	Duman A.D. et al., 2010
C. sativum var. *microcarpum*	Fruit	0.3-0.4	linalool 64-71	Telci et al., 2006b
	Fruit		linalool 91	Duman A.D. et al., 2010
	Fruit	0.35-0.61	linalool 37-77	Telci et al., 2006a
	Herba	0.5	(*E*)-2-decenal 17-35 (spring); 11-51 (summer) decanal 19-23 (autumn); 10-18 (summer)	Telci & Hisil, 2008a

PIMPINELLA ESSENTIAL OILS

The genus *Pimpinella* is represented in Turkey by 25 species, and altogether 29 taxa, 7 being endemic (Duran 2014). Essential oils of 20 taxa were analysed by our group. The results are summarized in Table 8.

Pimpinella oils are characterized by high contents of phenylpropanoid derivatives. Kubeczka has classified phenylpropanoids as two specific types, a propenylphenol-type (4-monosubstituted phenylpropanoid) and a pseudoisoeugenol-type (2,5-disubstituted phenylpropanoid) (Kubeczka, 1998). The 2-hydroxy-5-methoxy-1-(*E*)-propenylbenzene skeleton of these compounds, known as pseudoisoeugenol, is unique to *Pimpinella.* Trinorsesquiterpenes (geijerenes and azulenes) were also found to be characteristic constituents in most *Pimpinella* oils (Baser et al., 2007b)

Oil yields of the fruits of *Pimpinella* species were as follows: *P. nudicaulis* (5.10%), *P. anisetum* (5.3-5.05%), *P. aurea* (5.1%), *P. anisum* (4.8-1.3 %), *P. affinis* (2.12%), *P. cappadocica* var. *cappadocica* (2.06-0.3 %), *P. flabellifolia* (1.88%), *P. tragium* subsp. *pseudotragium* (1.87%), *P. saxifraga* (1.67%), *P. isaurica* (1.4-1.3%), *P. peregrina* (1.08%), *P. kotschyana* (1.02%), *P. tragium* subsp. *polyclada* (0.92%), *P. tragium* subsp. *lithophila* (0.73- 0.71%), *P. rhodantha* (0.41%), *P. puberula* (0.32%), *P. corymbosa* (0.26%), *P. peucedanifolia* (0.23*%), P. olivieroides* (0.20%). *P. aromatica* and *P. anisetum* roots gave the highest oil yields (4.2 and 3.2%, resp.). Oil yield of *P. aromatica* Herba was 6.1% and of *P. anisetum* 3.0%.

Oil of the cultivated anis (*Pimpinella anisum*) with 3-5% yield contained *trans*-anethole (85-96%) as the main constituent which crystallizes out easily by freezing. Crushed fruits of the endemic *P. anisetum* gave a high yield of oil (3-5%) with relatively high percentage of *trans*-anethole (55-83%) and methyl chavicol (22%). Herbaal parts of the same species yielded an oil also rich in *trans*-anethole (55%) and methyl chavicol (42%). The oil from Herbaal parts of *P. aromatica* obtained in high yield (6.1%) was a rich source of methyl chavicol (92%). Essential oil from roots of the same plant gave a totally different picture than the Herba in that the main constituent was 2-methylbutanoate of *trans*-pseudoeugenol (40%). Compounds responsible for the blue colour of the root oil were two azulene derivatives. Herba oil of *P. isaurica*, another endemic species, contained high proportion of angelic and tiglic acid esters of chavicol (44%). Fruits and Herbas of *P. cappadocica* (E) and *P. corymbosa* were relatively poor in essential oil. The oils contained sesquiterpenes as main constituents (Table 8).

Of the 22 isolated compounds during this investigation, two new phenylpropanoids, 4-(prop-2-enyl)phenyl angelate, and 4-(3-methyloxiranyl)phenyl 2-methylbutyrate, one new bisabolene-type sesquiterpenoid, 1-methyl-4-(6-methylhepta-1,5-dien-2-yl)-7-oxabicyclo [4.1.0]heptane (“aureane”), and one new trinorsesquiterpene, 4-(6-methylbicyclo[4.1.0]hept-2-en-7yl)butan-2-one (“traginone”), were identified and characterized by spectral techniques (Tabanca et al., 2006). Six further compounds were identified for the first time as constituents of Apiaceae, whilst *trans*-isoosmorhizole, was identified for the first time as a constituent of *Pimpinella* species. Nine known phenylpropanoids, as well as *trans*-anethole and methyl eugenol, were isolated and identified from different *Pimpinella* oils. The properties of known compounds were compared with previously published data, and after identification were registered in the “Baser Library of Essential Oil Constituents”.

Pimpinella oils were reanalyzed by GC/MS, and those isolated compounds were detected in other *Pimpinella* oils (Table 8). Oils from four *Pimpinella* taxa (*P. anisum, P. nudicaulis,* and two endemic taxa

P. anisetum, P. flabellifolia) were rich in *trans*-anethole. *Pimpinella anisetum* and *P. anisum* fruit oils were characterized by higher contents of *trans*-anethole (81–94 %) than the other species.

Trinorsesquiterpenes geijerene and pregeijerene were main constituents in the oils of *P. affinis* and *P. tragium* subsp. *lithophylla*. *P. saxifraga* and *P. puberula* oils were rich in monoterpenes and *P. peucedanifolia* oil was unique in having undecane (an alkane) as main constituent in the oil. *P. cappadocica, P. corymbosa, P. kotschyana, P. peregrina, P. tragium* subsp. *lithophila, P. tragium* subsp. *polyclada, P. tragium* subsp. *pseudotragium* oils were rich in sesquiterpenes.

Methyl eugenol was a major constituent in the oils of *P. oliveiroides* and *P. puberula.*

Table 8. *Pimpinella* oils of Turkey

Plant name	Part	% yield	Main components (%)	Ref.
P. affinis	Fruit	2.12	geijerene 59, pregeijerene 20, dictamnol 2, traginone 1*	Tabanca et al., 2006
	Stem+Leaf	0.09	geijerene 40, pregeijerene 11, traginone 5*, dictamnol 4, epoxypseudoisoeugenyl 2-methylbutyrate 0.2, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 0.2	Tabanca et al., 2006
	Root	0.23	geijerene 36, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 11, pregeijerene 9, epoxypseudoisoeugenyl 2-methylbutyrate 2, traginone 1*, dictamnol 1	Tabanca et al., 2006
P. anisum	Fruit	1.6	*trans*-anethole 96	Baser, 2002
		1.3-3.7	*trans*-anethole 79-95	Arslan et al., 2004
		2.8-4.8	*trans*-anethole 85-92	Ozel, 2009
		3.4	*trans*-anethole 85, methyl chavicol 16	Sampson et al., 2005
P. anisetum (E)	Fruit	5.3	*trans*-anethole 77, methyl chavicol 22	Baser et al., 1999a
		5.05	*trans*-anethole 81, methyl chavicol 16, 4-methoxy-2-(prop-(1*E*)-enyl)phenyl angelate 0.2	Tabanca et al., 2006
	Stem+Leaf	1.06	*trans*-anethole 54, epoxypseudoisoeugenyl 2-methylbutyrate 24, methyl chavicol 13, 4-methoxy-2-3-methyloxiranyl)-phenylangelate 5, 4-methoxy-2-(prop-(1*E*)-enyl)phenyl angelate 0.2, dictamnol 0.2	Tabanca et al., 2006
	Herba	3.0	*trans*-anethole 55, methyl chavicol 42	Baser, 2002
	Herba	2.07	*trans*-anethole 83, methyl chavicol 15	Tepe et al., 2006
	Root	3.2	epoxypseudoisoeugenyl 2-methylbutyrate 56, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 8, dictamnol 0.5,	Tabanca et al., 2006
P. aromatica	Herba	6.1	methyl chavicol 92, *trans*-anethole 7	Baser et al., 1996b
	Root	4.2	*trans*-epoxypseudoeugenyl-2-methylbutyrate 40, 4,10-dihydro-1,4-dimethylazulene 17, 1,4-dimethylazulene 9, pregeijerene 5	Baser et al., 1996b
P. aurea	Fruit	5.1	aureane 34*, β-bisabolene 33, 4-(prop-(1*E*)-enyl)phenyl tiglate 2.5, 4-(3-methyloxiranyl)phenyl-2-methylbutyrate* 1.2, 4-[(2*R*,3*R*)-3-methyloxiranyl]phenyl tiglate 0.3	Tabanca et al., 2006
	Stem+Leaf	0.3	aureane 20*, sabinene 20,α-pinene 12, b-bisabolene 9, 4-(prop-(1*E*)-enyl)phenyl tiglate 1.2, 4-(3-methyloxiranyl)phenyl-2-methylbutyrate* 0.4	Tabanca et al., 2006
	Root	0.1	epoxypseudoisoeugenyl 2-methylbutyrate 39, aureane 10*, 4-(3-methyloxiranyl)phenyl-2-methylbutyrate* 2, 4-(prop-(1*E*)-enyl)phenyl tiglate 1.6	Tabanca et al., 2006

P. cappadocica var. *cappadocica* (E)	Fruit	0.3	caryophyllene oxide 26	Baser, 2002
		2.06	bicyclogermacrene 12, γ-himachalene 9, β-caryophyllene 9, dehydrocostuslactone 8, sabinene 6, epoxypseudoisoeugenyl 2-methylbutyrate 0.1	Tabanca et al., 2006
	Stem+Leaf	0.14	sabinene 17, germacrene D 6, epoxypseudoisoeugenyl 2-methylbutyrate 0.6,	Tabanca et al., 2006
	Herba	0.7	himachalol 16	Baser, 2002
	Root	0.18	epoxypseudoisoeugenyl 2-methylbutyrate 43, 4-(1-propenyl)-phenyl-2-methylbutyrate 19, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 3, traginone 0.1*, 4-(prop-(1*E*)-enyl)phenyl tiglate 0.1, dictamnol 0.1	Tabanca et al., 2006
P. corymbosa	Fruit	0.2	β-caryophyllene 14, caryophyllene oxide 11	Baser, 2002
		0.3	β-caryophyllene 33, germacrene D 9, 12-hydroxy-β-caryophyllene acetate 5, 4,6-guaiadiene 0.6,	Tabanca et al., 2005
	Herba	0.1	β-caryophyllene 38, caryophyllene oxide 17	Baser, 2002
	Stem+Leaf	0.2	β-caryophyllene 33, germacrene D 12, 12-hydroxy-β-caryophyllene acetate 3, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.4, epoxypseudoisoeugenyl 2-methylbutyrate 0.1	Tabanca et al., 2005
	Root	0.2	epoxypseudoisoeugenyl-2-methylbutyrate 43, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 33, 4-(prop-(1*E*)-enyl)phenyl isobutyrate 0.5, 12-hydroxy-β-caryophyllene acetate 0.04	Tabanca et al., 2005
P. flabellifolia (E)	Fruit	1.88	*trans*-anethole 64, limonene 28,	Tabanca et al., 2006
	Stem+Leaf	0.85	*trans*-anethole 41, limonene 17, *trans*-isoosmorhizole 0.1	Tabanca et al., 2006
	Herba	2.61	limonene 47, trans-anethole 38	Tepe et al., 2006
	Root	1.43	*trans*-anethole 68, limonene 17, *trans*-isoosmorhizole 2	Tabanca et al., 2006
P. isaurica (E)	Herba	1.3	chavicyl angelate 44	Baser, 2002
	Stem+Leaf	0.3	4-(prop-2-enyl)phenyl angelate* 43, 4-(prop-(1*E*)-enyl)phenyl tiglate 13, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 3, 4-methoxy-2-(prop-(1*E*)-enyl)phenyl angelate 0.5,	Tabanca et al., 2006
	Fruit	1.43	α-zingiberene 16, 4-(prop-2-enyl)phenyl angelate* 14, 4-(prop-(1*E*)-enyl)phenyl tiglate 1.4, alismol 0.4, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 0.1	Tabanca et al., 2006
	Root	0.31	γ-terpinene 17, 4-(prop-(1*E*)-enyl)phenyl tiglate 16, 4-(prop-2-enyl)phenyl angelate* 11, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 7, 4-methoxy-2-(prop-(1*E*)-enyl)phenyl angelate 0.2	Tabanca et al., 2006

P.kotschyana	Fruit	1.02	β-caryophyllene 49, 12-hydroxy-β-caryophyllene acetate 12,α-humulene 11, 4,6-guaiadiene 2.1, 4-(Prop-(1*E*)-enyl)phenyl isobutyrate 0.3, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.1, dictamnol 0.01	Tabanca et al., 2006
	Stem+Leaf	0.06	β-caryophyllene 40, α-humulene 9, 12-hydroxy-β-caryophyllene acetate 5, 4,6-guaiadiene 2.4, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.3, dictamnol 0.1	Tabanca et al., 2006
	Root	0.10	epoxypseudoisoeugenyl 2-methylbutyrate 36, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 34, 4-(Prop-(1*E*)-enyl)phenyl isobutyrate 0.8, 4-methoxy-2-(3-methyloxiranyl)-phenylisobutyrate 0.7, 4,6-guaiadiene 0.6, dictamnol 0.3, 12-hydroxy-b-caryophyllene acetate 0.04	Tabanca et al., 2006
P. nudicaulis	Fruit	5.10	*trans*-anethole 64, *trans*-isoosmorhizole 21, aureane 0.02*	Tabanca et al., 2006
	Stem+Leaf	1.29	*trans*-anethole 28, α-pinene 17, β-pinene 15, *trans*-isoosmorhizole 12, sabinene 11, aureane 0.1*	Tabanca et al., 2006
	Root	0.31	*trans*-isoosmorhizole 79, *trans*-anethole 13, aurean 0.1*	Tabanca et al., 2006
P. oliveiroides	Fruit	0.20	methyl eugenol 71, *cis*-isoelemicine 14, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.1, epoxypseudoisoeugenyl 2-methylbutyrate 0.03	Tabanca et al., 2006
	Stem+Leaf	0.27	methyl eugenol 52, *cis*-isoelemicine 5, epoxypseudoisoeugenyl 2-methylbutyrate 0.5	Tabanca et al., 2006
	Root	0.06	4-(1-Prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 39, epoxypseudoisoeugenyl 2-methylbutyrate 33, 4,10-dihydro-1,4-dimethylazulene 6	Tabanca et al., 2006
P. peregrina	Fruit	1.1	*trans*-β-bergamotene 41, 4-methoxy-2-(3-methyloxiranyl)-phenylisobutyrate 4, aureane* 1, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.3	Tabanca et al., 2005
	Stem+Leaf	0.1	*trans*-β-bergamotene 70, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 8, 4-methoxy-2-(3-methyloxiranyl)-phenylisobutyrate 6, aureane* 3, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 2, *trans*-isoosmorhizole 0.3, 4,6-guaiadiene 0.1	Tabanca et al., 2005
	Root	0.1	4-methoxy-2-(3-methyloxiranyl)-phenylisobutyrate 45, epoxypseudoisoeugenyl-2-methylbutyrate 27, β-sesquiphellandrene 10, 4-(3-methyloxiranyl)phenyl-2-methylbutyrate * 0.3, aureane* 0.2, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.1, 4-methoxy-2-(3-methyloxiranyl)-	Tabanca et al., 2005

			phenylangelate 8,	
P. peucedanifolia	Fruit	0.23	undecane 77, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 2, 4-(prop-(1*E*)-enyl)phenyl isobutyrate 1.8, alismol 0.3	Tabanca et al., 2006
	Stem+Leaf	0.01	undecane 65, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 3, epoxypseudoisoeugenyl 2-methylbutyrate 0.8, dictamnol 0.3, 4-(Prop-(1*E*)-enyl)phenyl isobutyrate 0.1	Tabanca et al., 2006
	Root	0.13	epoxypseudoisoeugenyl 2-methylbutyrate 83, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 6, 4-methoxy-2-(3-methyloxiranyl)-phenylisobutyrate 2.4, 4-(3-methyloxiranyl) phenyl-2-methylbutyrate*1	Tabanca et al., 2006
P. puberula	Fruit	0.3	limonene 63, methyl eugenol 23, dictamnol 0.6, traginone* 0.2	Tabanca et al., 2005
	Stem+Leaf	0.2	limonene 37, methyl eugenol 30, dictamnol 3, traginone* 1, epoxypseudoisoeugenyl 2-methylbutyrate 0.1	Tabanca et al., 2005
P. rhodantha	Fruit	0.41	(*Z*)-β-farnesene 35, β-bisabolene 33, γ-himachalene 9, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 0.8, 4-Methoxy-2-(prop (1*E*)-enyl)phenyl tiglate 0.2	Tabanca et al., 2006
	Stem+Leaf	0.06	germacrene D 17, (*Z*)-β-farnesene 13, 4-methoxy-2-(3-methyloxiranyl)-phenyltiglate 6, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 2.5, alismol 1.4, epoxypseudoisoeugenyl 2-methylbutyrate 0.5, 4-Methoxy-2-(prop (1*E*)-enyl)phenyl tiglate 0.5, dictamnol 0.4	Tabanca et al., 2006
	Root	0.10	4-methoxy-2-(3-methyloxiranyl)-phenyltiglate 29, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 29, β-eudesmol 9, 4-Methoxy-2-(prop (1*E*)-enyl)phenyl tiglate 2, alismol 0.7, dictamnol 0.2, epoxypseudoisoeugenyl 2-methylbutyrate 0.2, traginone* 0.1	Tabanca et al., 2006
P. saxifraga	Fruit	1.67	sabinene 41, β-pinene 21, myrcene 14, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 1.5, 4-(3-methyloxiranyl)phenyl-2-methylbutyrate* 1, epoxypseudoisoeugenyl 2-methylbutyrate 0.2	Tabanca et al., 2006
	Stem+Leaf	0.32	β-pinene 28, myrcene 19, sabinene 14, limonene 11, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 1.3, epoxypseudoisoeugenyl 2-methylbutyrate 0.6, 4-(3-methyloxiranyl)phenyl-2-methylbutyrate* 0.3, *trans*-isoosmorhizole 0.1	Tabanca et al., 2006
	Root	0.17	epoxypseudoisoeugenyl 2-methylbutyrate 67, 4-(3-methyloxiranyl)phenyl-2-	Tabanca et al., 2006

			methylbutyrate* 4, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 3.3, dictamnol 0.2	
P. tragium ssp. *lithophila*	Fruit	0.73	β-bisabolene 30, geijerene 23, epoxypseudoisoeugenyl 2-methylbutyrate 2.5, traginone* 1, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.2, aureane 0.1*	Tabanca et al., 2006
	Stem+Leaf	0.22	geijerene 32, pregeijerene 8, dictamnol 6, traginone* 5, epoxypseudoisoeugenyl 2-methylbutyrate 4, 4,6-guaiadiene 0.3, aureane* 0.2	Tabanca et al., 2006
	Root	0.17	geijerene 27, 4,10-dihydro-1,4-dimethylazulene 14, 4,6-guaiadiene 7, traginone* 1, aureane* 0.2	Tabanca et al., 2006
P. tragium subsp. *polyclada*	Fruit	0.92	(*Z*)-β-farnesene 57, epoxypseudoisoeugenyl 2-methylbutyrate 20, 4-methoxy-2-[(2*R*,3*R*)-3-methyloxiranyl]phenyl tiglate 6, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 0.5	Tabanca et al., 2006
	Stem+Leaf	0.10	(*Z*)-β-farnesene 23, epoxypseudoisoeugenyl 2-methylbutyrate22, α-pinene 12, 4-methoxy-2-[(2*R*,3*R*)-3-methyloxiranyl]phenyl tiglate 5, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 1.5, 4-Methoxy-2-(prop (1*E*)-enyl)phenyl tiglate 0.5	Tabanca et al., 2006
	Root	0.22	4-methoxy-2-(3-methyloxiranyl)-phenylangelate 40, epoxypseudoisoeugenyl 2-methylbutyrate 16, 4-methoxy-2-[(2*R*,3*R*)-3-methyloxiranyl]phenyl tiglate 12, 4-Methoxy-2-(prop (1*E*)-enyl)phenyl tiglate 0.4	Tabanca et al., 2006
P. tragium subsp. *pseudotragium*	Fruit	1.87	β-bisabolene 19, α-pinene 16, epoxypseudoisoeugenyl-2-methylbutyrate 10, α-zingiberene 8, 4-(prop-(1*E*)-enyl)phenyl tiglate 0.8, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 0.8, *trans*-isoosmorhizole 0.6, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.2	Tabanca et al., 2006
	Stem+Leaf	0.08	α-pinene 31, β-bisabolene 6, epoxypseudoisoeugenyl 2-methylbutyrate 6, 4-(prop-(1*E*)-enyl)phenyl tiglate 0.4, *trans*-isoosmorhizole 0.3, 4-(1-prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate 0.2, 4-methoxy-2-(3-methyloxiranyl)-phenylangelate 0.2	Tabanca et al., 2006
	Root	0.11	4-methoxy-2-(3-methyloxiranyl)-phenylangelate 31, epoxypseudoisoeugenyl-2-methylbutyrate 19, traginone* 1, *trans*-isoosmorhizole 0.8, dictamnol 0.6, 4-(prop-(1*E*)-enyl)phenyl tiglate 0.5	Tabanca et al., 2006

*New compunds

SCALIGERIA OILS

Scaligeria is represented in Turkey by seven species of which two are endemic. *Scaligeria lazica* is an endemic species. Herbaal parts of this species has a strong smell of aniseeds due to the presence of *trans*-anethole in its oil. Fruit oil of the same species was found as a rich source of (*Z*)-b-Farnesene. After removal of the oil, aqueous distillate of the Herba was extracted with hexane. It contained phenolic aldehydes as main constituents (Baser et al., 1993; 1995).

Scaligeria tripartita fruit oil was rich in geijerenes and its root oil contained epoxypseudoisoeugenylangelate and geijerene (Tabanca, et al., 2007). Chemical proximity of *Pimpinella* and *Scaligeria* species is striking.

Table 9. *Scaligeria* oils of Turkey

Plant name	**Part**	**% yield**	**Main components (%)**	**Ref.**
Scaligeria lazica (E)	Herba	0.7	*trans*-anethole (50)	Baser et al., 1993.
	Fruit	2.2	(*Z*)-β-farnesene 89	Baser et al., 1995.
	Aqueous distillate of the Herba extracted with hexane		2-hydroxy-5-methoxybenzaldehyde 22, phenylacetaldehyde 14	Baser et al., 1993.
Scaligeria tripartita	Stem	tr	geijerene 37, (*Z*)-β-farnesene 9, β-bisabolene 9, dictamnol 9, lavandulyl acetate 9, pregeijerene 5, geijerene isomer 5	Tabanca, et al., 2007.
	Fruit	2.24	geijerene 55, geijerene isomer 12, β-bisabolene 7, pregeijerene 6, dictamnol 5	Tabanca, et al., 2007.

ECHINOPHORA OILS

Herbaal parts of all six species growing in Turkey have been studied. Fresh and dried leaves of *Echinophora tenuifolia* L. ssp. *sibthorpiana* (Guss.) Tutin which is known as "Çörtük, Turşu otu or Tarhana otu" in Turkish are added to meaty meals, pickles and soups for flavouring. According to previous as well as our studies, the oil of this species is characterised with a high percentage of methyl eugenol (18-59%) (Baser, et al., 1994). α-Phellandrene is another important compound also for the two endemic species *E. chrysantha* Freyn et Sint. (Baser et al., 1996a; Baser et al., 1998f) and *E. lamondiana* (Baser et al., 2000a). The latter is a recently described new species of *Echinophora* (Yıldız & Bahcecioglu, 1997). Main constituent of its oil was δ-3-carene (48%). The oil of *E. orientalis* revealed the occurrence of monoterpene hydrocarbons as main constituents. *E. trichophylla* J.E.Smith, endemic in Turkey, yielded 1.4% oil with sabinene (27%), terpinen-4-ol (16%) and (*E,E*)-cosmene (14%) as main constituents. Cosmene (2,6-dimethyl-1,3(*E*),5(*E*),7-octatetraene) was previously reported as a constituent of *Cosmos bipinnatus* Cav. several other Compositae plants and *Echinophora spinosa*, an European species (Kubeczka, 1988). This compound (2.1%) was also found in the oil of *E. orientalis* Hedge et Lamond which contained myrcene (34%) and *p*-cymene (19%) as main constituents. (*E,Z*)-

isomer of cosmene was found in the oil of *E. trichophylla* (Baser et al., 1998f). Oil poor species *E. tournefortii* Jaub. et Spach. and *E. carvifolia* Boiss. et Bal. (E) yielded oils rich in sesquiterpenes and the status of the latter has been transformed to the genus *Thecocarpus* as *T. carvifolius* (Duran, 2014) (Table 10).

Table 10. *Echinophora* oils of Turkey

Plant name	**Part**	**% yield**	**Main components (%)**	**Ref.**
E. carvifolia (E) *Thecocarpus carvifolius*	Herba	tr	germacrene D 31, β-caryophyllene 5	Baser et al., 1998f
E. chrysantha (E)	Herba	0.65	α-phellandrene 48-61, β-phellandrene 7-8	Baser et al., 1996a Baser et al., 1998f
E. lamondiana (E)	Herba	1.6	δ-3-carene 48, α-phellandrene 28, *p*-cymene 7	Baser et al., 2000a
E. orientalis	Herba	0.5	myrcene 34, *p*-cymene 19, (*E,E*)-cosmene 2	Baser et al., 1998f
E. tenuifolia		1.6	α-phellandrene 46, eugenol 30, *p*-cymene 24	Aridogan et al., 2002
E. tenuifolia subsp. *sibthorpiana*	Herba	1.0-1.7	methy leugenol 18-59, α-phellandrene 16-52, *p*-cymene 11-15	Baser et al., 1998f Baser et al., 1994
	Herba	0.76-2.4	methyl eugenol 10-81, γ-3-carene 2-63, α-phellandrene 11-30, *p*-cymene *tr*-10, β-phellandrene 3-5	Chalchat et al., 2007 Ozcan et al., 2002 Ozcan & Akgul, 2003
	Leaf	0.77	δ-3-carene 18, methyl eugenol 16, α-phellandrene 9, *p*-cymene 9	Gokbulut et al., 2013
E. trichophylla (E)	Herba	1.4	sabinene 27, terpinen-4-ol 16, 2,6-dimethyl-1,3(*E*),5(*E*),7-octatetraene [(*E,E*)-cosmene] 14	Baser et al., 1998f
E. tournefortii	Herba	0.2	caryophyllene oxide 13, α-pinene 10	Baser et al., 1998f
	Herba	0.18	myrcene 30, α-pinene 27	Demirci, B., et al., 2010a

FERULA OILS

Ferula is represented in the world by around 185 species. According to latest counts, Ferula taxa in Turkey numbers 24 with 23 species, 14 being endemic (Kurtoglu et al., 2013; Pimenov & Kljuykov, 2013; Duran, 2014). 17 taxa have been studied for their essential oils (Table 11)

Fruit oil yields varied between trace and 3.8%. High oil yielding species were as follows: *F. drudeana* 3.7-3.8%, *F. elaeochytris* 0.3-3.5%, *F. duranii* 2.6%, *F. coskunii* 2%, *F. mervynii* 2%, *F. parva* 2%, *F. brevipedicellata* 1.87%, *F. hermonis* 0.4-1.75%.

Fruit oils of most *Ferula* species are characterized by the high content of monoterpenes, especially α-pinene [*F. mervynii* 80%, *F. elaeochytris* 13-73%, *F. hermonis* 72%, *F. lycia* 15-69%, *F. brevipedicellata* 65%, *F. communis* 60%, *F. rigidula* 13-60%, *F. coskunii* 37%, *F. tingitana* 5-36%, *F. parva* 34%, *F. haussknechtii* 32%]; β-phellandrene *F. halophila* 14-72%, *F. orientalis* 24% (Herba)]. Sesquiterpenes are main constituents in the fruit oils of *F. anatolica* (germacrene D 30%), *F. duranii* (germacrene D 25%), *F. szowitsiana* [β and α-eudesmol 32+18 % (leaf); 30+17% (stem)], *F. drudeana* (shyobunone + epishyobunone + diepishyobunone 67%). Fruit oil of *F. szowitsiana* was rich in naphthalene (28%) and an unknown constituent (7%). Naphthalene was also encountered in a number of *Ferula* oils. *F. drudeana* and *F. szowitsiana* stand out by their different chemical composition of their oils among the *Ferula* species studied so far.

Table 11. *Ferula* oils

Plant name	**Part**	**% yield**	**Main components %**	**Ref.**
F. anatolica (E)	Fruit	tr	germacrene D 30, naphthalene 22, germacrene D-4-ol 4, δ-cadinene 3	Baser et al., 2007a
F. brevipedicellata (E)	Fruit	1.87	α-pinene 65, β-phellandrene 7, β-pinene 7, naphthalene 4	Baser et al., 2007a
F. communis	Fruit	0.09	α-pinene 60, β-pinene 17, naphthalene 4	Baser et al., 2007a
F. coskunii (E)	Fruit	2.0	sabinene 38, α-pinene 37, β-pinene 11	Baser et al., 2007a
F. drudeana (E)	Fruit	3.7	6-epi-isoshyobunone 38, shyobunone 25, diepishyobunone 6	Baser et al., 2007a
	Fruit	3.8	shyobunone 44, 6-epi-isoshyobunone 13, epi-shyobunone 10, β-pinene 6	Miski et al., 2012
F. duranii (E)	Fruit	2.6	germacrene D 25, naphthalene 10, α-copaene 6	Baser et al., 2007a
F. elaeochytris	Fruit	0.27	nonane 27, α-pinene 13, germacrene B 10	Baser et al., 2000c
	Fruit	3.5	α-pinene 73, β-pinene 15	Baser et al., 2007a
F. halophila (E)	Fruit	0.35	β-phellandrene 14, eremophilene 9	Baser et al., 2007a
	Fruit	0.62	β-phellandrene 38, eremophilene 7	Miski et al., 2013b
	cFr.	1.3	β-phellandrene 72, eremophilene 5	Miski et al., 2013b
F. haussknechtii	Fruit	0.88	α-pinene 32, camphene 31, myrcene 7, bornyl acetate 7, β-pinene 5	Baser et al., 2007a
F. hermonis	Fruit	0.41-1.75	α-pinene 72	Baser et al., 2007a
F. lycia (E)	Herba		α-pinene 60, β-pinene 19, limonene 3, bornyl acetate 2	Kose et al., 2010

	Fruit	0.58-1.35	1) naphthalene 27, α-pinene 26, β-pinene 26, caryophyllene oxide 5 2) naphthalene 17, α-pinene 15, caryophyllene oxide 11, germacrene B 4 3) α-pinene 69, β-pinene 4 4) α-pinene 67, β-phellandrene 5, β-caryophyllene 5, β-pinene 3 5) α-pinene 60, caryophyllene oxide 3, β-pinene 3, naphthalene 3	Baser et al., 2007a
F. mervynii (E)	Fruit	2	α-pinene 80, sabinene 12, β-pinene 9	Baser et al., 2007a
F. orientalis	Herba	0.51	β-phellandrene 24, (*E*)-β-ocimene 14, α-pinene 13, α-phellandrene 12, dehydrosesquicineole 10	Kartal et al., 2007
F. parva (E)	Fruit	2	α-pinene 34, eremophilene 9, naphthalene 5	Baser et al., 2007a
F. rigidula	Fruit		1) camphene 15, α-pinene 13, δ-cadinene 13, α-cadinol 10, germacrene D-4-ol 10 2) α-pinene 60, tricyclene 8, β-pinene 4, eremophilene 3 3) α-pinene 68, tricyclene 9, β-pinene 4	Baser et al., 2007a
	cFr.	0.8	α-pinene 24, camphene 20, germacrene D-4-ol 8, δ-cadinene 6, α-cadinol 5	Miski et al., 2013a
F. szowitsiana	Fruit		naphthalene 28, unknown 9,α-pinene 7, β-pinene 4, α-copaene 4, sabinene 4	Baser et al., 2007a
	Leaf	0.40	β-eudesmol 32, α-eudesmol 18, α-pinene 9	Ozek, G., et al., 2008
	Stem	0.05	β-eudesmol 30, α-eudesmol 17, α-pinene 6	Ozek, G., et al., 2008
F. tingitana	Fruit		1) naphthalene 15, α-pinene 11, unknown 7, daucene 6, (*Z*)-β-farnesene 5, β-pinene 5 2) α-pinene 36, β-pinene 14, naphthalene 14, germacrene D 5, (*Z*)-β-farnesene 4, daucene 3	Baser et al., 2007a

cFr: Crushed fruit;

FERULAGO OILS

Ferulago is represented by 35 taxa including 34 species 19 of which are endemic in the flora of Turkey (Davis et al.,1988; Duran 2014). 19 of them including 12 endemics were investigated by our group. The results of essential oil analyses are tabulated in Table 7. Percentage oil yields from some Ferulago fruits are quite high: *F. isaurica* 12%, *F. trachycarpa* 7.3%, *F. asparagifolia* 7%, *F. longistylis* 6.4%, *F. syriaca* 4.8%, *F. thirkeana* 4.1%, *F. humilis* 3.9%, *F. sandrasica* 3.9%, *F. pachyloba* 1.5%. Due to paucity of study materials, some species were subjected to microdistillation.

2,3,6-trimethylbenzaldehyde was the main constituent in the fruit oils of *F. asparagifolia* 39-42%, *F. platycarpa* 30%, *F. longistylis* 29%, *F. idaea* 14%, *F. syriaca* 9%, *F. setifolia* 6%. In the oil of *F. setifolia* 2,3,5-trimethylbenzaldehyde 78% was the main constituent. Herbal parts of *F. longistylis* contained 2,3,6-trimethylbenzaldehyde 33% in the oil. *p*-Cymene and its 2,3-dimethoxy derivative were main constituents of the fruit oils of *F. sylvatica* (86%), *F. confusa* (87%), *F. humilis* (E) (92%) and *F. idaea* (E)

(31%). Carvacrol methylether, on the other hand, was the main constituent of the fruit oil of *F. macrosciadia* (E) together with *p*-cymene. They were also among the main constituents is the oil of *F. idaea* (E).

trans-Chrysanthenylacetate was the main constituent of the fruit oils of *F. galbanifera* 17% and *F. silaifolia* (E) 84%. Oils of *F. sandrasica* 5-12% and *F. humilis* 12% also contained it. (*Z*)-β-ocimene was found as main constituent in the fruit oil of *F. trachycarpa* 31%, *F. pachyloba* 26%, *F. sandrasica* (E) 41%, *F. longistylis* 16% and another sample of *F. humilis* 32%. A second sample of *F. sandrasica* fruits yielded an oil rich in α-pinene and sesquiterpenoids like the fruit oils of *F. aucheri* (E) and *F. mughlae* (E). While herb oil of *F. trachycarpa* contained (*Z*)-β-ocimene as main constituent like its fruit, acyclic aldehydes were constituents of the root oil (Baser et al., 1998a).

Table 12. *Ferulago* oils of Turkey

Plant name	**Part**	**%**	**distn**	**Main components (%)**	**Ref.**
F. asparagifolia	Fruit	7.0	WD	2,3,6-trimethylbenzaldehyde 39, myrcene 18	Baser et al., 2001 Demirci, F., et al., 2000
			MD	2,3,6-trimethylbenzaldehyde 42, α-pinene 11	Baser et al., 2002a
F. aucheri (E)	Fruit		MD	α-pinene 21, caryophyllene oxide 8, spathulenol 7	Baser et al., 2002a
			MD	α-pinene 36, humulene epoxide II 7, *trans*-verbenol 6	Baser et al., 2002a
F. confusa	Fruit		MD	2,5-dimethoxy *p*-cymene 63, *p*-cymene 24	Kurkcuoglu et al., 2010
F. galbanifera	Fruit		MD	*trans*-chrysanthenyl acetate 17, *p*-cymene 12, α-phellandrene 11, limonene 10	Baser et al., 2002a
		1.3	WD	α-pinene 32, sabinene 16, limonene 7, α-phellandrene 6	Demirci, F., et al., 2000
F. humilis (E)	Fruit		MD	(*Z*)-β-ocimene 32, limonene 31	Baser et al., 2002a
			MD	2,5-dimethoxy *p*-cymene 76, *p*-cymene 16	Baser, 2002
		3.9	WD	(*Z*)-β-ocimene 32, limonene 17, α-pinene 12, *trans*-chrysanthenyl acetate 12	Demirci, F., et al., 2000
F. idaea (E)	Fruit		MD	*p*-cymene 18, α-pinene 16, 2,3,6-trimethylbenzaldehyde 14, carvacrol methylether 13, 2,5-dimethoxy *p*-cymene 13	Baser et al., 2002a
F. isaurica (E)	Fruit	12	WD	α-pinene 32, limonene 24, myrcene 17	Erdurak et al., 2006
	Herb	0.08	WD	nonacosane 26, hexadecanoic acid 15	Kilic et al., 2010a
	Root	0.7	WD	terpinolene 42, myrcene 27	Erdurak et al., 2006

F. longistylis (E)	Fruit	6.4	WD	2,3,6-trimethylbenzaldehyde 29, α-pinene 17, (*Z*)-β-ocimene 16, sabinene 6, myrcene 6, bornyl acetate 4	Ozkan et al., 2008
	Herb	0.16	WD	2,3,6-trimethylbenzaldehyde 33, bornyl acetate 13	Kilic et a.,l 2010a
F. macrosciadia (E)	Fruit		MD	carvacrol methylether 72-78, *p*-cymene 19-38	Baser et al., 2002a
F. mughlae (E)	Fruit		MD	α-pinene 25, cubenol 13, β-phellandrene 6	Baser et al., 2002a
F. pachyloba (E)	Herba	1.5	WD	(*Z*)-β-ocimene 26, α-pinene 10	Kilic et al., 2010a
F. platycarpa (E)	Herba	0.07	WD	2,3,6-trimethylbenzaldehyde 30, *cis*-chrysanthenylacetate 24	Kilic et al., 2010a
F. sandrasica (E)	Fruit	3.9	WD	(*Z*)-β-ocimene 32, limonene 17, α-pinene 12, *trans*-chrysanthenyl acetate 12	Baser, 2002
			MD	α-pinene 41, germacrene D 8, α-humulene 6, *trans*-chrysanthenyl acetate 5	Baser et al., 2002a
		0.6	WD	ocimene 31, δ-3-carene 27, α-pinene 18	Celik et al., 2013
F. setifolia	Herba	0.26	WD	2,4,5-trimethylbenzaldehyde 78, 2,3,6-trimethylbenzaldehyde 6	Baser et al., 2002a
F. silaifolia (E)	Fruit		MD	*trans*-chrysanthenyl acetate 84, α-pinene 6	Baser et al., 2002a
F. sylvatica	Fruit		MD	*p*-cymene 46, 2,5-dimethoxy *p*-cymene 40	Baser et al., 2002a
F. syriaca	Fruit	4.8	WD	myrcene 15, terpinolene 13, 4,6-guaiadiene 11, cubenol 9, 2,3,6-trimethylbenzaldehyde 9	Erdurak et al., 2006
	Root	1.1	WD	bornyl acetate 69, terpinolene 13	Erdurak et al., 2006
F. thirkeana (E)	Fruit	4.1	WD	ferulagone 64*, germacrene D 14, α-pinene 9	Baser et al., 2002a
			MD	ferulagone 56*, germacrene D 13, α-pinene 10	Baser et al., 2002a
F. trachycarpa	Fruit	7.3	WD	(*Z*)-β-ocimene 31, myrcene 28	Baser et al., 1998b
	Herba	0.6	WD	(*Z*)-β-ocimene 34, α-pinene 8	Demirci, F., et al., 2000
	Root	0.02	WD	octanal 10, (*E*)-2-decenal 7	Baser, 2002
	Fruit		MD	γ-terpinene 28, *p*-cymene 22, myrcene 20	Baser et al., 2002a

* New compounds

HERACLEUM OILS

Heracleum is represented in Turkey by 21 taxa comprising 17 species including 7 endemics. Essential oil compositions of the fruits of five species have been investigated. *Heracleum* fruits are characterised with high oil yield and high proportion of aliphatic esters in their oils. Octyl acetate was the main constituent in the oils of *H. crenatifolium* (19-95%), *H. platytaenium* (73-88%), *H. paphlagonicum* (27-95%). Hexyl butyrate was the main compound in the oil of *H. argaeum* (39%). Octyl butyrate and

octanol were the main constituents of the oils of *H. sphondylium* subsp. *ternatum* (25-43% and 39-50%, resp.)

Table 13. *Heracleum* oils of Turkey

Plant name	Part	% yield	Main components (%)	Ref.
H. argaeum (E)	Fruit	1.24	hexyl butyrate 39, octyl hexanoate 9, octyl acetate 7, octylbutyrate 6	Baser et al., 1998c
H. crenatifolium (E)	Fruit	3.66	octyl acetate 19-95, octanol 1-5, octyl isovalerate 1-6, decyl acetate 1-4	Ozek, T., et al., 2005 Iscan et al., 2004
	Fruit	5.5	octyl acetate 88, octanol 3, (*Z*)-4 octenyl acetate 1	Tosun et al., 2008
H. paphlagonicum (E)	Fruit	4.9-7.4	octyl acetate 27-95, hexyl butyrate 17-25	Baser et al., 2000e
H. platytaenium (E)	Fruit	5.2-6.8	octyl acetate 73-77, octyl butyrate 12-17	Kurkcuoglu et al., 1995
	Fruit	5.33	octyl acetate 88, octyl hexanoate 3-5, (Z)-4-octenyl acetate 2, octanol 1, decanal 1	Ozek, T., et al., 2005 Iscan et al., 2004
	Herba		octyl acetate 86, octyl hexanoate 13, (Z)-4-octyl acetate 2, octyl octanoate 1	Akcin et al., 2013
H. sphondylium subsp. *ternatum*	Fruit	3.7	octanol 39-50, octyl butyrate 25-27, octyl acetate 7-11	Ozek, T., et al., 2002 Iscan et al., 2003
	Fruit	MD	octyl butyrate 43, octyl acetate 31, octanol 9	Ozek, T., et al., 2002
	Fruit	2.0	octyl butyrate 35-41, apiole 5-20, (*Z*)-4-octenyl acetate 2-4, (*Z*)-4-octenyl butyrate 3	Ozek,T., et al., 2005 Iscan et al., 2004

Fruits of *Zosima absinthifolia* (Baser et al., 2000c) and *Malabaila secacul* (Demirci, B., et al., 2006) yielded oils also rich in aliphatic esters. The former which is the only *Zosima* species recorded in Turkey is a close relative of the genus *Heracleum* and contains octanol esters as main constituents. Likewise, *Pastinaca sativa* subsp. *urens* fruit oil also contained octanol esters as main constituents (Kurkcuoglu et al., 2006a). *Pastinaca* is represented in Turkey by 4 taxa including 3 species comprising one endemic. Main constituents of the *Malabaila* oil were hexanol esters. *Malabaila* is represented in the flora of Turkey by six species.

Table 14. *Zosima, Pastinaca* and *Malabaila* oils of Turkey

Plant name	Part	% yield	Main components (%)	Ref.
Zosima absinthifolia	Fruit	0.9	octyl acetate 38, octyl hexanoate 32	Baser et al., 2000c
Pastinaca sativa subsp*. urens*	Fruit	2.5	octyl butyrate 80, octyl hexanoate 5, phenylethyl butyrate 2	Kurkcuoglu et al., 2006a
Malabaila secacul	Fruit	1.05	hexyl hexanoate 73, hexyl octanoate 9	Demirci, B., et al., 2006

TORDYLIUM OILS

Tordylium is represented in Turkey by 17 species, nine being endemic. Fruit oils of nine species have been investigated. Except for *T. aegyptiacum* in which hexadecanoic acid (40%) was the main component, oils of all the other species investigated contained octanol esters as main constituents like in the case of *Heracleum* oils. Octyl hexanoate predominated the oils of *T. apulum* (44%), *T. hasselquistiae* (73%), *T. lanatum* (E) (59%), *T. pestalozzae* (E) (56%), *T. pustulosum* (E) (73%), *T. syriacum* (46-81%), while octyl octanoate was a major constituent in the oils of *T. ketenoglui* (E) (73%), *T. trachycarpum* (80%), *T. apulum* (35%).

Table 15. *Tordylium* oils of Turkey

Plant name	Part	yield %	Main component %	Ref.
T. aegyptiacum	Fruit	<0.1	hexadecanoic acid 40, β-caryophyllene 11, octyl octanoate 9, caryophyllene oxide 9	Tosun et al., 2010
T. apulum	Fruit	MD	octyl hexanoate 44, octyl octanoate 35, octanol 17	Baser et al., 2002b
T. hasselquistiae	Fruit	0.5	octyl hexanoate 73, octyl octanoate 13, octanol 3	Ozek, T., et al., 2007a
T. ketenoglui (E)	Fruit	0.3	octyl octanoate 29, octanol 12, bornyl acetate 7	Tosun et al., 2007
T. lanatum (E)	Fruit	0.15	octyl hexanoate 59, octanol 22	Tosun et al., 2006b
T. pestalozzae (E)	Fruit	0.3	octyl hexanoate 56, octyl octanoate 16, octanol 15, hexadecanoic acid 6	Tosun et al., 2006b
T. pustulosum (E)	Fruit	MD	octyl hexanoate 73, octanol 10	Baser et al., 2002b
	Fruit	3.3	octyl hexanoate 69, octyl 2-methylbutyrate 18, octanol 4	Tosun et al., 2006b
T. syriacum	Fruit	0.1-0.7	octyl hexanoate 46-81, octanol 1-8, α-humulene 2-7, 2,3,4-trimethylbenzaldehyde 1-5	Kurkcuoglu et al., 2012
T. trachycarpum	Fruit	1.85	octyl octanoate 80, octanol 11, octanoic acid 3	Ozek, T., et al., 2007a

SMYRNIUM OILS

Seven *Smyrnium* species are recorded in the flora of Turkey. Three of them have been investigated for essential oils. The results are summarised in Table 16. Root oils of *S. olusatrum* and *S. perfoliatum* were investigated by our group (Baser, 2002).

Furanosesquiterpenes are characteristic constituents of *Smyrnium* oils. Isofuranogermacrene was found as main constituent in the root oils of *S. olusatrum* and *S. perfoliatum* and the fruit oil of *S. rotundifolium*. Furanodiene was a major constituent in the root and fruit oils of *S. perfoliatum* and fruit oil of *S. rotundifolium*. Fruit oils of *S. perfoliatum* from two different locations yielded germacrene D and α-selinene as main constituents, respectively. The former also contained acetoxy-furanoeudesmenes (Kubeczka & Molleken, 1999; Molleken et al., 1998).

Table 16. *Smyrnium* oils of Turkey

Plant name	**Part**	**% yield**	**Main components (%)**	**Ref.**
S. olusatrum	Root		isofuranogermacrene 51	Baser, 2002
S. perfoliatum	Fruit	0.7	germacrene D 45-47, 1β-acetoxyfuranoeudesm-3-ene 9	Kubeczka & Molleken, 1999;
	Fruit	0.2	α-selinene 31, furanodiene 20, germacrene D 9	Molleken et al., 1998
	Root		isofuranogermacrene 48,	Baser, 2002
S. rotundifolium	Fruit		isofuranogermacrene 35-45, furanodiene 28-39	Kubeczka & Molleken, 1999

PRANGOS OILS

The genus *Prangos* is represented by 19 taxa including 19 species in the flora of Turkey and ten of them are endemic. Essential oils of nine species were subjected to analysis. Results are listed in Table 17.

The endemic *P. denticulata* root yielded 3.2% oil. *P. platychlaena* (E) and *P. euchtritzii* (E) fruits yielded 1.4-2.7% and 0.7-2.1% oils, resp. Oil yields of the other species investigated gave <1% essential oil.

P. denticulata (E), *P. ferulacea, P. ilanae, P. platychlaena* (E) and *P. uechtritzii* (E) oils were rich in monoterpenes while *P. heyniae* (E), *P. pabularia, P. turcica* (E) and *P.* sp. nova (E) oils were predominated by sesquiterpenes.

The oil from intact and crushed fruits of *P. ferulacea* contained the same monoterpene hydrocarbons as major components with γ-terpinene as the main constituent. However, the distilled oil from fruits crushed after distillation contained sesquiterpenes, germacrene B and germacrene D as main constituents together with γ-terpinene (Baser et al., 1996c).

Prangos heyniae is a recently described species (Duman & Watson, 1999). Oils from fruits collected from two nearly localities yielded β-bisabolene and its alcohol and aldehyde (Baser et al., 2000b). β-Bisabolenal and β-bisabolenol were first reported as constituents of *Neocallitropis pancheri* (Carriere) de Laubeufels (Cupressaceae) (Raharivelomanana et al., 1993). This is the second report on the occurrence of these rare sesquiterpenes in nature.

Main component in the oil of *P. uechtritzii* fruits was a new monoterpene 7-epi-1,2-dehydrosesquicineole (13%). Acetylenic compound 3,5-nonadiyn-2-ene and its esters were among the

main components of the fruit oil of *P. platychlaena*; and 3,5-nonadiyn-7-ene in the root oil of *P. denticulata*.

The status of *Prangos bornmuelleri* has recently been changed to a new genus, hence renamed as *Ekimia bornmuelleri* (Duman, H. & Watson, 1999). Steam volatiles of the fruits of this species were published (Baser et al., 1999). The results are summarised in Table 28 under *Ekimia bornmuelleri*.

Table 17. *Prangos* oils of Turkey

Plant name	**Part**	**yield %**	**Main component %**	**Ref.**
P. denticulata (E)	Fruit	tr	sabinene 26, *p*-cymene 20	Kilic et al., 2010b
	Root	3.2	δ-3-carene 49, (*Z*)-3,5-nonadiyn-7-ene 20	Kilic et al., 2010b
P. ferulacea	Fruit	0.36	γ-terpinene 33, α-pinene 13, *p*-cymene 11, (*E*)-β-ocimene 8, (*Z*)-β-ocimene 4	Baser et al., 1996c
	cFr	0.97	γterpinene 30, α-pinene 18, *p*-cymene 10, (*E*)-β-ocimene 8, (*Z*)-β-ocimene 7	Baser et al., 1996c
	Frcad	0.98	germacrene B 30, γ-terpinene 17, germacrene D 8, α-pinene 5, *p*-cymene 5, (*E*)-β-ocimene 4, (*Z*)-β-ocimene 4	Baser et al., 1996c
	Herba		2,3,6-trimethylbenzaldehyde 67, chrysanthenyl acetate 15, *p*-mentha-1,5-dien-8-ol 4, β-ocimene 4, α-pinene 3	Sumer Ercan et al., 2013
P. heyniae (E)	Fruit	0.3- 0.9	β-bisabolenal 18-53, β-bisabolenol 2-15, β-bisabolene 10-12, germacrene D 3-14, germacrene B 2- 9	Baser et al., 2000b
P. ilanae	Herba	0.2	α-phellandrene 31, *p*-cymene 19, β-phellandrene 13, limonene 4, α-pinene 3	Kurkcuoglu&Baser personal comm.
P. pabularia	Fruit	0.2	α-humulene 17, bicyclogermacrene 16, spathulenol 11, germacrene D 6, α-pinene 4	Ozek, G., et al., 2007b
P. platychlaena (E)	Fruit	0.4	α-pinene 70, β-phellandrene 11	Uzel et al., 2006
P. platychlaena subsp *platychlaena* (E)	Fruit	1.4-2.7	3,5-nonadiyn-2-yl acetate 11-45, 3,5-nonadiyne 6-25, 3,5-nonadiyn-2-yl acetate isomer 4, β-phellandrene 4-23, α-phellandrene 0.1-18, α-pinene 7-13	Tabanca et al., 2009
P. turcica (E)	Fruit	0.37	α-humulene 11, germacrene D 11, naphthalene 9, terpinolene 8, bornyl acetate 7, germacrene D-4-ol 5, α-pinene 4, *p*-cymene 4	Ozek, G., et al., 2006a
P. uechtritzii (E)	Fruit	0.76	7-epi-1,2-dehydrosesquicineole 13*, α-pinene 8, β-phellandrene 7, α-bisabolol 5	Baser et al., 2000f
	Fruit	MD	α-pinene 11, β-phellandrene 8, *p*-cymene 6, 14-hydroxy-δ-cadinene 5	Baser et al., 2000f
	Fruit	2.1	α-pinene 41, nonene 17, β-phellandrene 8, δ-3-carene 7, *p*-cymene 5	Uzel et al., 2006
	Herba	0.7	*p*-cymene 11, γ-terpinene 7, β-phellandrene 8, α-phellandrene 6, (*Z*)-β-ocimene 5	Ozcan et al., 2000
P. sp. nova (E)	Fruit	0.65	germacrene D 50, α-cadinol 9, δ-cadinene 6	Duran and Duman personal comm.

cFr: Crushed fruit; Frcad: Crushed after distillation of the whole fruit; MD: Microdistillation; * New Compound

SESELI OILS

14 taxa belonging to 13 species including four endemics are recorded in the Flora of Turkey, seven being endemic. Seven taxa including three endemics have been investigated for essential oils. Main constituents are listed in Table 18.

Oil yields over 1% were as follows: *S. petraeum* (Herb-3.4%), *S. resinosum* (Herb-2.3%; Fruit-2.1%), *S. tortuosum* (Fruit-2.2%), *S. campestre* (Fruit-1.5%; Herb-1%).

Three species yielded sesquiterpene-rich oils: *S. andronakii* (E), *S. libanotis, S. gummiferum* subsp. *corymbosum* (E).

In the oils of five species, monoterpenes and sesquiterpenes were mixed major constituents: *S. campestre, S. gummiferum* subsp. *corymbosum* (E), *S. petraeum*, *S. resinosum* (E), *S. tortuosum*.

In the oils of *S. campestre* and *S. tortuosum*, α-pinene and (*E*)-sesquilavandulol were mixed major constituents.

Table 18. *Seseli* oils of Turkey

Plant name	**Part**	**% yield**	**Main components (%)**	**Ref.**
S. andronakii (E)	Fruit	2.1	carotol 53, germacrene D 9	Tosun et al., 2006a
S. campestre	Herba	1.0	α-pinene 36, myrcene 6, sabinene 6, limonene 6, bornyl acetate 5	Baser et al., 2000d
	Fruit	1.5	α-pinene 26, (*E*)-sesquilavandulol 12, myrcene 9	Baser et al., 2000d
	Fruit	1	α-pinene 36, (*E*)-sesquilavandulol 3	Baser et al., 2000d
S. gummiferum subsp. *corymbosum* (E)	Herba	0.8	α-pinene 9, sabinene 7, β-elemene 6, spathulenol 6	Baser, 2002
	Herba		bicyclogermacrene 12, germacrene B 14	Tosun et al., 2005
S. gummiferum subsp. *gummiferum*	Herba		spathulenol 20	Tosun et al., 2005
S. libanotis	Herba		β-caryophyllene 20, spathulenol 12, caryophyllene oxide 12, euasarone 11, δ-cadinene 9	Ozturk & Ercisli, 2006
S. petraeum	Herba	3.4	carotol 21, γ-terpinene 11, sabinene 10, germacrene D 8	Tosun et al., 2006a
S. resinosum (E)	Herba	2.3	4α-hydroxy germacra-1(10)- 5-diene 30, β-pinene 16, germacrene D 14	Baser, 2002
	Fruit	2.1	β-pinene 38, 4α-hydroxy germacra-1(10)- 5-diene 22, α-pinene 14	Dogan et al., 2006
S. tortuosum	Fruit	2.2	(*E*)-sesquilavandulol 37, sabinene 20, α-pinene 14, β-phellandrene 8	Dogan et al., 2006
	Herba	0.32	α-pinene 36, sabinene 19, (*E*)-sesquilavandulol 8, β-pinene 7	Kaya et al., 2003

LASERPITIUM OILS

There are five species of *Laserpitium* of which two are endemic in Turkey. Main constituents are listed in Table 19.

Root oil of *L. hispidum* yielded myristicin as the main constituent along with monoterpenes. Herba oil of the endemic species *L. petrophyllum* contained monoterpene hydrocarbons as main constituents (Baser & Duman, 1997) (Table 19).

Table 19. *Laserpitium* oils of Turkey

Plant name	**Part**	**% yield**	**Main components (%)**	**Ref.**
L. hispidum	Root	0.4	myristicin 25, γ-terpinene 15, sabinene 13, terpinolene 12	Baser, 2002
L. petrophyllum (E)	Herba	1.3	α-pinene 49, sabinene 26	Baser & Duman, 1997

JOHRENIA OILS

Johrenia is represented in the Flora of Turkey with 7 species comprising 3 endemics. Five of them have been studied for their essential oils. Main constituents are listed in Table 20.

Essential oils of the endemic species *J. alpina, J. polyscias* and *J. silenoides* were rich in monoterpenes while sesquiterpenes were the predominating components in the oils of *J. dichotoma* and *J. tortuosa.* Methylfarnesoate, a sesquiterpene, was present in the fruit oils of *J. tortuosa* (43%), *J. dichotoma* (17%) and *J. silenoides* (9%).

Table 20. *Johrenia* oils of Turkey

Plant name	**Part**	**yield %**	**Main component %**	**Ref.**
J. alpina (E)	Fruit		α-pinene 39, β-pinene 5	Ozek, T., et al., 2009
	Herba	0.03	dodecanoic acid 24, α-pinene 12, β-bisabolene 6, β-caryophyllene 5, hexadecanoic acid 4	Ozek, T., et al., 2009
J. dichotoma	Fruit	0.02	methylfarnesoate 17, bicyclogermacrene 13, hexadecanoic acid 7, β-caryophyllene 6, spathulenol 5, α-pinene 3	Ozek, T., et al., 2009
J. polyscias (E)	Fruit	0.02	α-pinene 23, β-pinene 14, hexadecanoic acid 9, bicyclogermacrene 6,	Ozek, T., et al., 2009
	Herba		α-pinene 19, β-pinene 18, limonene 7, spathulenol 6, hexadecanoic acid 5	Ozek, T., et al., 2009
J. silenoides (E)	Fruit	0.1	spathulenol 15, α-pinene 34, β-pinene 14, methylfarnesoate 9, germacrene D 5	Ozek, T., et al., 2009
	Herba		spathulenol 13, α-pinene 8, β-pinene 5, *p*-cymene 4, limonene 3,	Ozek, T., et al., 2009
J. tortuosa	Fruit	0.02	methylfarnesoate 43, α-pinene 7, β-pinene 5, β-caryophyllene 5, bicyclogermacrene 5, hexadecanoic acid 3	Ozek, T., et al., 2009
	Herba		hexadecanoic acid 9, unknown 6, unknown 5, pentacosane 5, tetradecanoic acid 4	Ozek, T., et al., 2009

BUPLEURUM OILS

Bupleurum is represented in Turkey by 49 taxa comprising 47 species including 21 endemics. Flower, fruit and root essential oil of 12 of them have been analyzed. Main constituents are listed in Table 21.
Bupleurum is an oil poor genus of Apiaceae. Alkanes were the predominating volatiles in majority of *Bupleurum* oils. Undecane was the main constituent in *B. cappadocicum* (Fruit 50%; Root 23%), *B. croceum* (Fruit 13%), *B. gerardii* (Flower 37%; Fruit 49%), *B. intermedium* (Root 63%), *B. sulphureum* (Flower 14%; Fruit 20%); tridecane in *B. lycaonicum* (Flower 15%; Fruit 37%), *B. rotundifolium* (Root 12%); pentacosane in *B. turcicum* (Root 9%); hexacosane in *B. lancifolium* (Fruit 13%). Hexadecanoic acid was the main constituent in the oil of *B. croceum* (Root 35%), *B. heldreichii* (Root 46%), *B. lancifolium* (Root 14%), *B. rotundifolium* (Flower 12%). Heptanal was the main constituent in the oils of *B. cappadocicum* (Flower 47%), *B. turcicum* (Flower 33%; Fruit 24%) and hexanal in *B. gerardii* (Root 22%). Methyl linoleate was the main constituent in the flower oil of *B. intermedium* (21%).
Monoterpenes were present in the oils of the following species as main constituents: a-pinene in *B. falcatum* subsp. *cernuum* (Flower 41%; Fruit 42%), *B. rotundifolium* (Flower 9-28%; Fruit 11%), b-phellandrene in *B. rotundifolium* (Flower 7-19%).
Sesquiterpenes were the main constituent in the oils of a number of *Bupleurum* species. Germacrene D in *B. croceum* (Flower 13%), *B. heldreichii* (Flower and Fruit 48% each), *B. intermedium* (Fruit 26%), *B. pauciradiatum* (Flower 12-46%); spathulenol in *B. lancifolium* (Flower 15%), *B. lycaonicum* (Root 14%); β-caryophyllene in *B. pauciradiatum* (Flower 10-12%); calarene in *B. sulphureum* (Root 27%).

Table 21. *Bupleurum* oils of Turkey

Plant name	**Part**	**yield %**	**Main component %**	**Ref.**
B. cappadocicum	Flower		heptanal 47	Saracoglu et al., 2012
	Fruit		undecane 50	Saracoglu et al., 2012
	Root		undecane 23	Saracoglu et al., 2012
B. croceum (E)	Flower		germacrene D 13	Saracoglu et al., 2012
	Fruit		undecane 13	Saracoglu et al., 2012
	Root		hexadecanoic acid 35	Saracoglu et al., 2012
B. falcatum subsp. *cernuum* (E)	Flower		α-pinene 41	Saracoglu et al., 2012
	Fruit		α-pinene 42	Saracoglu et al., 2012
	Root		amylfuran 23	Saracoglu et al., 2012
B. gerardii (E)	Flower		undecane 37	Saracoglu et al., 2012
	Fruit		undecane 49	Saracoglu et al., 2012
	Root		hexanal 22	Saracoglu et al., 2012
B. heldreichii (E)	Flower		germacrene D 48	Saracoglu et al., 2012
	Fruit		germacrene D 48	Saracoglu et al., 2012
	Root		hexadecanoic acid 46	Saracoglu et al., 2012
B. intermedium (E)	Flower		methyl linoleate 21	Saracoglu et al., 2012
	Fruit		germacrene D 26	Saracoglu et al., 2012
	Root		undecane 63	Saracoglu et al., 2012
B. lancifolium (E)	Flower		spathulenol 15	Saracoglu et al., 2012
	Fruit		hexacosane 13	Saracoglu et al., 2012
	Root		hexadecanoic acid 14	Saracoglu et al., 2012
B. lycaonicum (E)	Flower		tridecane 15	Saracoglu et al., 2012

	Fruit		tridecane 37	Saracoglu et al., 2012
	Root		spathulenol 14	Saracoglu et al., 2012
B. pauciradiatum (E)	Flower		germacrene D 46, β-caryophyllene 18	Saracoglu & Akin 2009a
	Flower	MD	germacrene D 12, β-caryophyllene 10	Saracoglu & Akin 2009a
B. rotundifolium (E)	Flower	n-hexane	hexadecanoic acid 12	Akin et al., 2012
	Flower		α-pinene 9, β-phellandrene 7	Saracoglu & Akin 2009b
	Flower	MD	α-pinene 28, β-phellandrene 19	Saracoğlu & Akin 2009b
	Fruit	n-hexane	α-pinene 11	Akin et al., 2012
	Root	n-hexane	undecane 26, tridecane 12	Akin et al., 2012
B. sulphureum (E)	Flower		undecane 14	Saracoglu et al., 2012
	Fruit		undecane 20	Saracoglu et al., 2012
	Root		calarene 27	Saracoglu et al., 2012
B. turcicum (E)	Flower		heptanal 33	Saracoglu et al., 2012
	Fruit		heptanal 24	Saracoglu et al., 2012
	Root		pentacosane 9	Saracoglu et al., 2012

MD: Microdistilled

OTHER APIACEAE OILS

This part of the treatise comprises the remaining Apiaceae genera not covered in previous pages according to main constituents in their oils. The lists also contain species treated previously. Hence, Apiaceae oils rich in monoterpene-hydrocarbons (Table 22), aliphatic aldehydes (Table 23), alkanes (Table 24), alkanol (Table 25), aliphatic esters (Table 26), phenylpropanoids (Table 27) and sesquiterpenes (Table 28).

Tables 29-37 display Apiaceae species according to main constituents within the groups of compounds contained in the essential oils.

Table 22. Monoterpene-rich Oils

Plant name	**Part**	**% yield**	**Main components (%)**	**Ref.**
Angelica sylvestris var. *sylvestris*	Fruit	0.26	α-pinene 26, β-phellandrene 9, bornyl acetate 7, *p*-cresol 7	Ozek, T. et al., 2008
Artedia squamata	Fruit	trace	*trans*-verbenol 14, carvacrol 10, hexadecanoic acid 10	Baser, 2002
Bilacunaria anatolica (E)	Fruit	0.17	α-pinene 26, camphene 19, β-caryophyllene 11	Kurkcuoglu&Baser Personal Comm.
	Herba	0.14	α-pinene 27, caryophyllene oxide 14	Kurkcuoglu&Baser Personal Comm.
Chaerophyllum byzantinum (E)	Herba	0.8	sabinene 30, *p*-cymen-8-ol 16, terpinolene 12	Kurkcuoglu et al., 2006
Chaerophyllum libanoticum	Fruit	1.5	β-phellandrene 18, limonene 16, β-pinene 9, sabinene 9	Demirci, B., et al., 2007
Chaerophyllum macropodum (E)	Fruit	MD	*p*-cymene 39	Baser et al., 2006
Crithmum maritimum	Herba	0.85	sabinene 27, limonene 24, γ-terpinene 19	Baser et al., 2000g

	Herba	0.18-0.28	γ-terpinene 8-35, methyl thymol 8-30, *p*-cymene 5-27, terpinen-4-ol 1-21, sabinene 0.1-21, dill apiole 0.1-21, (*Z*)-β-ocimene 1-13	Ozcan et al., 2001
	Herba	0.17 0.19	1) β-phellandrene 30, methylthymol 25 2) γ-terpinene 24, dill apiole 21	Senatore et al., 2000
	Herba	0.2	γ-terpinene 32-36, β-phellandrene 21-22, sabinene 9-13	Ozcan et al., 2006
Daucus littoralis	Herba	0.2	*cis*-chrysanthenyl acetate 47	Baser et al., 2009
Diplotaenia hayri-dumanii (E)	Fruit	MD	α-pinene 26, 2,5-dimethoxy-*p*-cymene 25, β-pinene 18	Kurkcuoglu&Baser Personal Comm.
Diplotaenia cachrydifolia	Leaf	1.67	terpinolene 65, (*E*)-isodillapiole 18, b-phellandrene 5	Ozcan et al., 2004
	Root	0.33	(isomyristicin 21), α-phellandrene 19, β-phellandrene 10, methyl oleate 10, *p*-cymene 8, (*E*)-isodillapiole 6	Ozcan et al., 2004
	Fruit	2.9	terpinolene 69, (*E*)-isodillapiole 8, β-phellandrene 7, (*E*)-β-ocimene 5	Ozcan et al., 2004
Eryngium campestre	Herba	0.34	α-pinene 5	Celik et al., 2011
Eryngium thorifolium	Herba	0.68	α-pinene 59	Celik et al., 2011
Fuernrohria setifolia	Herba	MD	limonene 48, carvon 14, β-elemene 9	Ozek, T. et al., 2010
	Fruit	MD	limonene 70, carvone 25	Ozek, T. et al., 2010
Glaucosciadium cordifolium	Herba	0.7	limonene 40, α-pinene 12, β-pinene 10	Baser et al., 2000m
Lagoecia cuminoides	Herba	0.9-1.1	thymol 73-95	Baser & Tumen, 1994
Laserpitium petrophilum (E)	Herba	1.34	α-pinene 49, sabinene 26	Baser & Duman, 1997
Peucedanum graminifolium (E)	Fruit	L-N	thymol 63, carvacrol 23, β-pinene 12	Baser, 2002
Peucedanum palimbioides	Herba	0.53	α-pinene 53, (*E*)-9-octadecanoic acid 24, β-pinene 20	Tepe et al., 2011
Trachyspermum copticum	Fruit		thymol 61, *p*-cymene 16, γ-terpinene 12	Monguzzi & Akgül, 1993
Xanthogalum purpurascens ***(Angelica purpurascens)***	Fruit	0.8	α-phellandrene 32, β-phellandrene 23, isopropylhexanoate 6, limonene 5, *p*-cymene 4, α-pinene 3, bicyclogermacrene 12	Ozek, G., et al., 2006b

L-N: Likens-Nickerson simultaneous distillation-extraction; MD: Microdistilled

Table 23. Aliphatic aldehyde-rich Oils

Plant name	**Part**	**% yield**	**Main components (%)**	**Ref.**
Bifora radians	Herba	0.4	(*E*)-2-tridecenal 47, (*E*)-2-tetradecenal 23	Baser et al., 1998g
Cymbocarpum wiedemannii	Fruit	0.3	(*E*)-decenal 39, (*E*)-2-dodecenal 16, (*E*)-2-tetradecenal 9	Baser et al., 1999b
	Herba	0.6	(*E*)-2-decenal 32, 2-decenoic acid 20. (*E*)-2-dodecenal 11, decanoic acid 9	Baser et al., 1999b
Eryngium creticum	Herba	0.21	Hexanal 53, heptanal 14, octane 9	Celik et al., 2011

Table 24. Alkane-rich Oils

Plant name	Part	% yield	Main components (%)	Ref.
Heptaptera anatolica	Fruit	<0.1	nonacosane 24, heptacosane 23	Yılmaz et al., 2009
Heptaptera anisoptera	Fruit	<0.1	nonacosane 69, heptacosane 10, hexadecanoic acid 7, pentacosane 2, octacosane 2	Yılmaz et al., 2009
Heptaptera cilicica (E)	Fruit	<0.1	nonacosane 39, heptacosane 11, pentacosane 6, hexahydrofarnesylacetone 5, (*E*)-geranylacetone 4	Yılmaz et al., 2009
Heptaptera triquetra	Fruit	<0.1	nonacosane 42, heptacosane 23	Yılmaz et al., 2009
Hippomarathrum cristatum ***(Cachrys cristata)***	Herba	0.4	hexadecanoic acid 12, nonacosane 8, germacrene D 6, myristicin 4	Ozek, G., et al 2007a

Table 25. Alkanol-rich Oil

Plant name	Part	% yield	Main components (%)	Ref.
Actinolema macrolema	Leaf	n-hexane	1-octadecanol 24, hexadecanoic acid 19	Demirci, B., et al., 2013

Table 26. Aliphatic ester-rich Oils

Plant name	Part	% yield	Main components (%)	Ref.
Hippomarathrum microcarpum ***(Bilacunaria microcarpa)***	Herba	0.74	Bornyl acetate 20, caryophyllene oxide 8, β-caryophyllene 6, *trans*-verbenol 6, β-elemene 4, germacrene D 3	Ozer et al., 2007
Malabaila secacul	Fruit	1.05	Hexyl hexanoate 73, hexyl octanoate 9	Demirci, B., et al., 2006
Pastinaca sativa subsp. *urens*	Fruit	2.5	Octyl butyrate 80, octyl hexanoate 5, phenylethyl butyrate 2	Kurkcuoglu et al., 2006a
Zosima absinthifolia	Fruit	0.9	octyl acetate 38, octyl hexanoate 32	Baser et al., 2000c

Table 27. Phenylpropanoid-rich Oils

Plant name	Part	% yield	Main components (%)	Ref.
Anthriscus cerefolium	Herba	0.42	methyl chavicol 83, 1-allyl-2,4-dimethoxybenzene 15, undecane 2	Baser et al., 1998a
Myrrhoides nodosa ***(Physocaulis nodosa)***	Herba	0.1	methyl chavicol 74, 1-allyl-2,4-dimethoxybenzene 12	Tumen et al., 2005
Scandix australis subsp. *grandiflora*	Herba	0.4	methyl chavicol 96	Tumen & Baser 1997
Scandix iberica	Fruit	*n*-hexane	methyl chavicol 91	Kaya et al., 2007
	Flower	*n*-hexane	methyl chavicol 86	Kaya et al., 2007

Table 28. Sesquiterpene-rich Oils

Plant name	Part	% yield	Main components (%)	Ref.
Actinolema macrolema	Fruit	2.3	guaia-5,7(11)-diene 37, germacrene B 25, selina-3,7(11)-diene12, γ-guaiene 11	Demirci, B., et al., 2013
Bilacunaria aksekiensis (E)	Fruit	0.26	β-caryophyllene 41, caryophyllene oxide 8, germacrene B 8, α-humulene 7	Kurkcuoglu& Baser Personal Comm.
Cachrys alpina (***Prangos ilanae***)	Fruit	MD	α-humulene 33	Baser et al., 2004
Chaerophyllum aksekiense (E)	Fruit	1.1	(heptacosane 10), humulene epoxide II 8, (*E*)-β-farnesene 6, caryophyllene oxide 6, α-humulene 6, terpinolene 6	Baser et al., 2000h
Cnidium silaifolium subsp. *orientale* (E)	Herba	0.09	kessane 33, α-copaene 11, β-caryophyllene 8, α-pinene 8, δ-cadinene 7	Polat et al., 2011
Ekimia bornmuelleri (E)	Fruit	L-N	germacrene D-4-ol 43, α-cadinol 19, δ-cadinene 11	Baser et al., 1999
Grammosciadium pterocarpum	Fruit	MD	(*Z*)-β-farnesene 57, β-caryophyllene 11, γ-terpinene 10, β-elemene 8	Ozek, T., et al., 2007b
	Leaf	MD	(*Z*)-β-farnesene 11, β-caryophyllene 10, γ-terpinene 2, γ-elemene 1	Ozek, T., et al., 2007b
Hippomarathrum boissieri ***(Bilacunaria boissieri)***	Herba	0.4	β-caryophyllene 26, caryophyllene oxide 9, α-pinene 9	Baser et al., 2000k
Kundmania anatolica (E)	Fruit	MD	caryophyllene oxide 31, muurola-4,10(14)-dien-1-ol 26, δ-cadinene 15	Kurkcuoglu& Baser Personal Comm..
	Herba	MD	caryophyllene oxide 19, δ-cadinene 14, β-bisabolone 13, muurola-4,10(14)-dien-1-ol 12	Kurkcuoglu & Baser Personal Comm..
Neocryptodiscus papillaris	Fruit	0.12	α-humulene 20, β-caryophyllene 17, germacrene D 7	Ozek, G. et al., 2010
Olymposciadium caespitosum (E) ***(Aegokeras caespitosa)***	Fruit	Tr	germacrene D 31, β-ylangene 9, β-cubebene isomer 6, bicyclosesquiphellandrene 5, γ-gurjunene 3, eudesma-4(15),7-dien-1β-ol 3, octanal 3	Kurkcuoglu & Baser Personal Comm..
Peucedanum longifolium	Herba	0.75	8-cedren-13-ol 34, myristicin 8, germacrene D 7, δ-3-carene 6	Tepe et al 2011
Rhabdosciadium microcalycinum	Herba	0.2	germacrene D 25	Baser et al., 2006
	Herba	MD	germacrene D 33	Baser et al., 2006
Rhabdosciadium oligocarpum (E)	Herba	0.6	germacrene D 62	Baser et al., 2006
	Herba	MD	germacrene D 62	Baser et al., 2006
Szovitsia callicarpa	Fruit	0.6	α-kessyl acetate 65, longipinene 19	Demirci. B., et al., 2010b
Trinia glauca	Fruit	1.1	germacrene D 20, δ-cadinene 13, α-pinene 13	Baser et al., 1998d
Xanthogalum purpurescens ***(Angelica purpurascens)***	Fruit	0.2	bicyclogermacrene 12, β-phellandrene 7, spathulenol 7, kessane 7	Ozek, G., et al., 2006b

IMPORTANT CONSTITUENTS

Table 29. Monoterpene Hydrocarbons [Taxon (plant part) %]

α-Pinene	*Ferula mervynii* (Fr) 80, *Ferula elaeochytris* (Fr) 13-73, *Ferula hermonis* (Fr) 72, *Prangos platychlaena* (Fr) 70, *Ferula lycia* (Fr) 15-69, (H) 60; *Ferula brevipedicellata* (Fr) 65, *Ferula communis* (Fr) 60, *Ferula rigidula* (Fr) 13-60, *Eryngium thorifolium* (H) 59, *Peucedanum palimbioides* (H) 53, *Laserpitium petrophilum* (H) 49, *Bupleurum falcatum* ssp. *cernuum* (Fl) 41, (Fr) 42; *Prangos uechtritzii* (Fr) 11-41, *Ferulago sandrasica* (Fr) 12-41, *Johrenia alpina* (Fr) 39, *Ferula coskunii* (Fr) 37, *Seseli campestre* (H) 26-36, (Fr) 26; *Seseli tourtuosum* (H) 36, (Fr) 14; *Ferulago aucheri* (Fr) 21-36, *Ferula tingitana* (Fr) 11-36, *Ferula parva* (Fr) 34, *Johrenia silenoides* (Fr) 34, *Ferula haussknechtii* (Fr) 32, *Ferulago isaurica* (Fr) 32, *Ferulago galbanifera* (Fr) 32, *Pimpinella tragium* ssp. *pseudotragium* (S+L) 31, *Bupleurum rotundifolium* (Fl) 9-28, *Echinophora tournefortii* (H) 10-27, *Bilacunaria anatolica* (H) 27, (Fr) 26, *Diplotaenia hayri-dumanii* (Fr) 26, *Angelica sylvestris* var. *sylvestris* (S) 26, *Ferulago mughlae* 25, *Johrenia polyscias* (Fr) 23, (H) 19; *Prangos ferulacea* (Fr) 13-18, *Pimpinella nudicaulis* (H) 17, *Ferulago longistylis* (Fr) 17, *Ferulago idaea* (Fr) 16, *Pimpinella tragium* ssp. *pseudotragium* (S+L) 31, (Fr) 16; *Trinia glauca* (Fr) 13, *Ferula orientalis* (Fr) 13, *Prangos platychlaena* ssp. *platychlaena* (Fr) 7-13, *Pimpinella tragium* ssp. *polyclada* (S+L) 12, *Glaucosciadium cordifolium* (H) 12, *Johrenia alpina* (H) 12, *Pimpinella aurea* (S+L) 12, *Ferulago humulis* (Fr) 12, *Bupleurum rotundifolium* (Fr) 11, *Ferulago asparagifolia* (Fr) 11, *Ferulago thirkeana* (Fr) 10, *Ferulago pachyloba* (H) 10
β-Pinene	*Seseli resinosum* (Fr) 38, *Pimpinella saxifragra* (S+L) 28, (Fr) 21; *Ferula lycia* (Fr) 26, (H) 19; *Peucedanum palimbioides* (H) 20, *Johrenia polyscias* (H) 18, *Diplotaenia hayri-dumanii* (Fr) 18, *Ferula communis* (Fr) 17, *Seseli resinosum* (H) 16, *Cuminum cyminum* (Fr) 3-16, *Ferula elaeochytris* (Fr) 15, *Pimpinella nudicaulis* (S+L) 15, *Ferula tingitana* (Fr) 5-14, *Johrenia silenoides* (Fr) 14, *Peucedanum graminifolium* (Fr) 12, *Ferula coskunii* (Fr) 11, *Glaucosciadium cordifolium* (H) 10
p-cymene	*Ferulago sylvatica* (Fr) 46, *Chaerophyllum macropodum* (Fr) 39, *Ferulago macrosciadia* (Fr) 19-38, *Chritmum maritimum* (H) 5-27, *Diplotenia hayri-dumani* (Fr) 25, *Ferulago confusa* (Fr) 24, *Ferulago trachycarpa* (Fr) 22, *Prangos denticulata* (Fr) 20, *Echinophora orientalis* (H) 19, *Prangos ilanae* (H) 19, *Ferulago idea* (Fr) 18, *Cuminum cyminum* (Fr) 5-18, *Ferulago humilis* (Fr) 16, *Trachyspermum copticum* (Fr) 16, *Echinophora tenuifolia* ssp. *sibthorpiana* (H) 11-15, *Ferulago galbanifera* (Fr) 12, *Prangos uechtritzii* (H) 11, *Prangos ferulacea* (Fr) 10-11
Sabinene	*Ferula coskunii* (Fr) 38, *Chaerophyllum byzantinum* (H) 30, *Echinophora trichophylla* (H) 27, *Crithmum maritimum* (H) 5-27, *Laserpitium petrophilum* (H) 26, *Prangos denticulata* (Fr) 26, *Ferula galbanifera* (Fr) 26, *Seseli tortuosum* (Fr) 20, (H) 19; *Pimpinella tragium* ssp. *lithophila* (Fr) 16, *Laserpitium hispidum* (R) 13, *Ferula mervynii* (Fr) 12, *Seseli petraeum* (H) 10
Camphene	*Ferula haussknechtii* (Fr) 31, *Ferula rigidula* (Fr) 15-20, *Bilacunaria anatolica* (Fr) 19
Myrcene	*Echinophora orientalis* (H) 34, *Echinophora tournefortii* (H) 30, *Ferulago trachycarpa* (Fr) 20-28, *Ferulago isaurica* (R) 27, (Fr) 17; *Pimpinella saxifragra* (S+L) 19, (Fr) 14; *Ferulago asparagifolia* (Fr) 18, *Ferulago syriaca* (Fr) 15, *Seseli campestre* (Fr) 9
α-phellandrene	*Echinophora chrysantha* (H) 48-61, *Echinophora tenuifolia* ssp. *sibthorpiana* (H) 16-52, *Angelica purpurascens* (Fr) 32, *Prangos ilanae* (H) 31, *Echinophora lamondiana* (H) 28, *Diplotaenia cachrydifolia* (R) 19, *Prangos platychlaena* ssp. *platychlaena* (Fr) 0.1-18, *Ferula orientalis* (H) 12, *Ferulago galbanifera* (Fr) 11
β-phellandrene	*Ferula halophila* (Fr) 14-72, *Crithmum maritimum* (H) 21-30, *Ferula orientalis* ((H) 24, *Prangos platychlaena* ssp. *platychlaena* (Fr) 4-23, *Angelica purpurascens* (Fr) 23, *Bupleurum rotundifolium* (Fl) 7-19, *Chaerophyllum libanoticum* (Fr) 18, *Prangos ilanae* (H) 13, *Prangos platychlaena* (Fr) 11, *Diplotaenia cachrydifolia* (R) 10, *Prangos uechtritzii* (Fr) 7-8
δ-3-carene	*Prangos denticulata* (R) 49, *Echinophora lamondiana* (H) 48
γ-terpinene	*Apium graveolens* (H) 39, *Prangos ferulacea* (Fr) 30-33, *Cuminum cyminum* (Fr) 7-32, *Ferulago trachycarpa* (Fr) 28, *Crithmum maritimum* (H) 8-35, *Laserpitium hispidum* (R) 15, *Trachyspermum copticum* (Fr) 12, *Seseli petraeum* (H) 11, *Grammosciadium pterocarpum*

	(Fr) 10
Limonene	*Laser trilobum* (Fr) 6-91, *Fuernrohria setifolia* (Fr) 70, (H) 48; *Pimpinella puberula* (Fr) 63, (S+L) 37, *Pimpinella flabellifolia* (S+L) 17-47, (Fr) 28, (R) 17; *Glaucosciadium cordifolium* (H) 40, *Ferulago humilis* (Fr) 31, *Pimpinella isaurica* (Fr) 24, *Crithmum maritimum* (H) 24, *Ferulago sandrasica* (Fr) 17, *Chaerophyllum libanoticum* (Fr) 16, *Pimpinella saxifraga* (H) 11, *Foeniculum vulgare* var. *azoricum* (Fr) 8-11, *Ferulago galbanifera* (Fr) 10
Terpinolene	*Diplotaenia cachrydifolia* (Fr) 69, (L) 65*; Ferulago isaurica* (R) 42*, Ferulago syriaca* (Fr) 13, (R) 13, *Laserpitium hispidum* (R) 12, *Chaerophyllum byzantinum* (H) 12
(*Z*)-β-ocimene	*Ferulago trachycarpa* (H) 34, *Ferulago humilis* (Fr) 32, *Ferulago sandrasica* (Fr) 32, *Ferulago trachycarpa* (Fr) 31, *Ferulago pachyloba* (H) 26, *Ferulago longistylis* (Fr) 16, *Crithmum maritimum* (H) 1-13
(E)-β-ocimene	*Ferula orientalis* (H) 14

Table 30. Oxygenated Monoterpenes

Linalool	*Coriandrum sativum* var. *microcarpum* (Fr) 37-91*Coriandrum sativum* (Fr) 72-83, *Coriandrum sativum* var. *macrocarpum* (Fr) 79, *Coriandrum sativum* var. *vulgare* (Fr) 30-65,
Terpinen-4-ol	*Crithmum maritimum* (H) 1-21, *Echinophora trichophylla* (H) 16
trans-Verbenol	*Artedia squamata* (Fr) 14
Carvone	*Anethum graveolens* (Fr) 46-66, *Fuernrohria setifolia* (Fr) 25
Fenchone	*Foeniculum vulgare* var. *piperitum* (Fr) 18-28
Thymol	*Lagoecia cuminoides* (H) 73-95, *Peucedanum graminifolium* (Fr) 63, *Trachyspermum copticum* (Fr) 61
Carvacrol	*Peucedanum graminifolium* (Fr) 23, *Artedia squamata* (Fr) 10
Carvacrol methyl ether	*Ferulago macrosciadia* (Fr) 72-78, *Ferulago idaea* (Fr) 13
2,5-Dimethoxy-*p*-cymene	*Ferulago humilis* (Fr) 76, *Ferulago confusa* (Fr) 63, *Ferulago sylvatica* (Fr) 40, *Diplotaenia hayri-dumanii* (Fr) 25, *Ferulago idaea* (Fr) 13
trans-Chrysanthenyl acetate	*Ferulago silaifolia* (Fr) 84, *Ferulago galbanifera* (Fr) 17, *Ferulago sandrasica* (Fr) 12, *Ferulago humulis* (Fr) 12
cis-Chrysanthenyl acetate	*Daucus littoralis* (H) 47, *Ferulago platycarpa* (H) 24
Cuminaldehyde	*Cuminum cyminum* (Fr) 19-40
p-Mentha-1,4-dien-7-al	*Cuminum cyminum* (Fr) 2-49
p-Mentha-1,3-dien-7-al	*Cuminum cyminum* (Fr) 4-13
Ferulagone (NEW)	*Ferulago thirkeana* (Fr) 56-64
p-cymen-8-ol	*Chaerophyllum byzantinum* (H) 16
Methyl thymol	*Crithmum maritimum* (H) 8-30

Table 31. Phenyl propanoids

1-Allyl-2,4-dimethoxybenzene	*Anthriscus cerefolium* (H) 15, *Physocaulis nodosa* (H) 12
trans-Anethole	*Pimpinella anisum* (Fr) 96-94, *Foeniculum vulgare* var. *dulce* (Fr) 95, *Foeniculum vulgare* var. *vulgare* (Fr) 65-88, *Foeniculum vulgare* var. *azoricum* (Fr) 59-72, *Pimpinella anisetum* (Fr) 81-77, (S+L) 54; *Pimpinella flabellifolia* (R) 68, (Fr) 64, (S+L) 41, (H) 38; *Pimpinella nudicaulis* (Fr) 64, (S+L) 28, (R) 13; *Scaligeria lazica* (H) 50
Methyl chavicol	*Scandix australis* ssp. *grandiflora* (H) 96, *Pimpinella aromatica* (H) 92, *Scandix iberica* (Fr) 91, (Fl) 86; *Anthriscus cerefolium* (H) 83, *Physocaulis nodosa* (H) 74, *Foeniculum vulgare* var. *piperitum* (Fr) 63-73, (L) 25-70, (S) 61, (R) 59; *Pimpinella anisetum* (H) 15-42, (Fr) 16-22, (S+L) 13; *Pimpinella anisum* (Fr) 16, *Foeniculum vulgare* var. *vulgare* (Fr) 4-16
Chavicyl angelate	*Pimpinella isaurica* (H) 44
trans-Epoxypseudoeugenyl 2-	*Pimpinella aromatica (*R) 40

methylbutyrate	
Epoxypseudoisoeugenyl 2-methylbutyrate (= 4-Methoxy-2-[(2*R*,3*R*)-3-methyloxiranyl]phenyl(2*S*)-methylbutyrate)	*Pimpinella peucedanifolia* (R) 83, *Pimpinella saxifraga* (R) 67, *Pimpinella anisetum* (R) 56, *Pimpinella cappadocica* (R) 43, *Pimpinella corymbosa* (R) 43, *Pimpinella aurea* (R) 39, *Pimpinella kotschyana* (R) 36, *Pimpinella olivieroides* (R) 33, *Pimpinella peregrina* (R) 27, *Pimpinella anisetum* (S+L) 24, *Pimpinella tragium* ssp. *polyclada* (Fr) 20, *Pimpinella tragium* ssp. *pseudotragium* (R) 19, *Pimpinella tragium* ssp. *polyclada* (R) 16, *Pimpinella tragium* ssp. *pseudotragium* (Fr) 10
Methyl eugenol	*Pimpinella olivieroides* (Fr) 71, (S+L) 52, (R) 1; *Echinophora tenuifolia* ssp. *sibthorpiana* (H) 18-59, *Pimpinella puberula* (Fr) 30, (S+L) 23; *Pimpinella rhodantha* (Fr) 0.2
Myristicin	*Laserpitium hispidum* (R) 25
Isomyristicin	*Diplotaenia cachrydifolia* (R) 21
2,3,4,5-Tetramethoxy allylbenzene	*Petroselinum sativum* (Fr) 29
4-(Prop-2-enyl)phenyl angelate (NEW)	*Pimpinella isaurica* (S+L) 43, (Fr) 14, (R) 11
4-(3-Methyloxiranyl)phenyl-2-methylbutyrate (NEW)	*Pimpinella saxifraga* (R) 4, (Fr) 0.7, (S+L) 0.3; *Pimpinella aurea* (R) 2, (Fr) 1.2, (S+L) 0.4; *Pimpinella peucedanifolia* (R) 1, *Pimpinella peregrina* (R) 0.3
trans-Isoosmorhizole	*Pimpinella nudicaulis* (R) 79, (Fr) 21, (S+L) 12; *Pimpinella flabellifolia* (R) 2, (H) 0.1; *Pimpinella tragium* ssp. *pseudotragium* (R) 1, (Fr) 0.6, (S+L) 0.3; *Pimpinella peregrina* (S+L) 0.3, *Pimpinella saxifraga* (S+L) 0.1
4-(1-Prop-(1*E*)-enyl)phenyl (2*S*)-methylbutyrate (= Anethol 2-methylbutyrate)	*Pimpinella olivieroides* (R) 39, (Fr) 0.1; *Pimpinella kotschyana* (R) 34, (S+L) 0.3, (Fr) 0.1; *Pimpinella corymbosa* (R) 33, (S+L) 0.4; *Pimpinella peucedanifolia* (R) 6, (S+L) 3, (Fr) 2; *Pimpinella saxifraga* (R) 3, (Fr) 1.5, (S+L) 1.3; *Pimpinella peregrina* (S+L) 2, (Fr) 0.3, (R) 0.1; *Pimpinella tragium* ssp. *lithophila* (Fr) 0.2; *Pimpinella tragium* ssp. *pseudotragium* (S+L) 0.2, (Fr) 0.2
4-(Prop-(1*E*)-enyl)phenyl isobutyrate	*Pimpinella peucedanifolia* (Fr) 2, (S+L) 0.1; *Pimpinella kotschyana* (R) 1, (S+L) 0.3, (Fr) 0.3; *Pimpinella corymbosa* (R) 0.5
4-(Prop-(1*E*)-enyl)phenyl tiglate = anol tiglate	*Pimpinella isaurica* (R) 16, (S+L) 12, (Fr) 1.4; *Pimpinella aurea* (Fr) 3, (R) 2, (S+L) 1; *Pimpinella tragium* ssp. *pseudotragium* (Fr) 1, (R) 1, (S+L) 0.4; *Pimpinella cappadocica* var. *cappadocica* (R) 0.1
4-[(2*R*,3*R*)-3-Methyloxiranyl]phenyl tiglate	*Pimpinella aurea* (Fr) 0.3
4-Methoxy-2-(prop-(1*E*)-enyl)phenyl angelate	*Pimpinella isaurica* (S+L) 0.5, (R) 0.2; *Pimpinella anisetum* (S+L) 0.2, (Fr) 0.2
4-Methoxy-2-[(2*R*,3*R*)-3-methyloxiranyl]phenyl tiglate	*Pimpinella tragium* ssp. *polyclada* (R) 12, (Fr) 6, (S+L) 5; *Pimpinella isaurica* (R) 2, (S+L) 0.3); *Pimpinella cappadocica* var. *cappadocica* (R) 1; *Pimpinella peregrina* (S+L) 1, (R) 0.04; *Pimpinella olivieroides* (R) 1, *Pimpinella anisetum* (S+L) 0.3, (R) 0.1; *Pimpinella aurea* (R) 0.2, *Pimpinella affinis* (R) 0.1
4-Methoxy-2-[(2*R*,3*S*)-3-methyloxiranyl]phenylisobutyrate	*Pimpinella peregrina* (R) 45, (S+L) 6, (Fr) 4; *Pimpinella peucedanifolia* (R) 2.4, *Pimpinella kotschyana* (R) 1
4-Methoxy-2-(prop (1*E*)-enyl)phenyl tiglate	*Pimpinella rhodantha* (R) 2, (S+L) 0.2, (Fr) 0.2; *Pimpinella tragium* ssp. *polyclada* (S+L) 1, (R) 0.4
pseudoisoeugenyl 2-methylbutyrate	*Pimpinella aurea* (R) 4, (S+L) 0.1; *Pimpinella saxifraga* (R) 2, *Pimpinella tragium* ssp. *polyclada* (S+L) 1, (Fr) 1, (R) 0.01; *Pimpinella tragium* ssp. *pseudotragium* (R) 1, (Fr) 1, (S+L) 0.3; *Pimpinella peregrina* (R) 1, *Pimpinella anisum* (Fr) 1, *Pimpinella cappadocica* var. *cappadocica* (R) 1, *Pimpinella tragium* ssp. *lithophila* (R) 1, (Fr) 0.1
4-Methoxy-2-[(2*R*,3*R*)-3-	*Pimpinella tragium* ssp. *polyclada* (R) 40, (S+L) 2, (Fr) 1; *Pimpinella*

methyloxiranyl]phenylangelate	*tragium* ssp. *pseudotragium* (R) 31, (Fr) 1, (S+L) 0.2; *Pimpinella rhodantha* (R) 29, (S+L) 3, (Fr) 1; *Pimpinella affinis* (R) 11, (S+L) 0.2; *Pimpinella anisetum* (R) 8, (S+L) 5; *Pimpinella peregrina* (S+L) 8, *Pimpinella isaurica* (R) 7, (S+L) 3, (Fr) 0.1; *Pimpinella cappadocica* var. *cappadocica* (R) 3
cis-Isoelemicine	*Pimpinella olivieroides* (Fr) 14, (H) 5
Dill apiole	*Crithmum maritimum* (H) 0.1-21
(E)-Isodillapiole	*Diplotaenia cachrydifolia* (L) 18, (Fr) 8, (R) 6

Table 32. Aldehydes

2,3,6-Trimethylbenzaldehyde	*Ferulago asparagifolia* (Fr) 39-42, *Ferulago idaea* (Fr) 14
2-Hydroxy-5-methoxy-benzaldehyde	*Scaligeria lazica* (Hydrosol)22
Phenylacetaldehyde	*Scaligeria lazica* (Hydrosol) 14
(*E*)-2-Decenal	*Coriandrum sativum* (H) 11-51*, Cymbocarpum wiedemannii* (Fr) 39, *Cymbocarpum wiedemannii* (H) 32, *Ferulago trachycarpa* (R) 7
Decanal	*Coriandrum sativum* (H) 10-23
Octanal	*Ferulago trachycarpa* (R) 10
(E)-2-Dodecenal	*Cymbocarpum wiedemannii* (Fr) 16, *Cymbocarpum wiedemannii* (H) 11
(E)-2-Tridecenal	*Bifora radians* (H) 47
(E)-2-Tetradecenal	*Bifora radians* (H) 23*, Cymbocarpum wiedemannii* (Fr) 9
Heptanal	*Bupleurum cappadocicum* (Fl) 47, *Bupleurum turcicum* (Fl) 33, (Fr) 24; *Eryngium creticum* ((H) 14
Hexanal	*Eryngium creticum* (H) 53, *Bupleurum gerardii* (R) 22

Table 33. Alkane derivatives

2,6-Dimethyl-1,3(*E*),5(*E*),7-octatetraene (= (*E,E*)-cosmene)	*Echinophora trichophylla* (H) 14
2-Decenoic acid	*Cymbocarpum wiedemannii* (H) 20
Decanoic acid	*Cymbocarpum wiedemannii* (H) 9
Hexadecanoic acid	*Bupleurum heldreichii* (R) 46, *Tordylium aegypticum (*Fr) 40, *Bupleurum croceum* (R) 35, *Actinolema macrolema* (L) 19, *Ferulago isaurica* (H) 15, *Bupleurum lancifolium* (R) 14, *Bupleurum rotundifolium* (Fl) 12*, Cachrys cristata* (H) 12, *Artedia squamata* (Fr) 10, *Johrenia polycias* (Fr) 9, *Johrenia tortuosa* (H) 9
Nonane	*Ferula elaeochytris* (Fr) 27
Nonene	*Prangos uechtritzii* (Fr) 17
Dodecanoic acid	*Johrenia alpina* (H) 24*,*
Undecane	*Pimpinella peucedanifolia* (Fr) 77, (S+L) 65, *Bupleurum intermedium* (R) 63, *Bupleurum cappadocicum* (Fr) 50, (R) 23*; Bupleurum gerardii* (Fr) 49, (Fl) 37; *Bupleurum rotundifolium* (R) 26, *Bupleurum sulphureum* (Fr) 20, (Fl) 14; *Bupleurum croceum* (Fr) 13,
Methyl linoleate	*Bupleurum intermedium* (Fl) 21,
Hexacosane	*Bupleurum lancifolium* (Fr) 13
Tridecane	*Bupleurum lycaonicum* (Fr) 37, (Fl) 15; *Bupleurum rotundifolium* (R) 12
Pentacosane	*Bupleurum turcicum* (R) 9
Methyl oleate	*Diplotaenia cachrydifolia* (R) 10
(*E*)-9-octadecanoic acid	*Peucedanum palimbioides* (H) 24
Nonacosane	*Heptaptera anisoptera* (Fr) 69*, Heptaptera triquetra* (Fr) 42, *Heptaptera cilicica* (Fr) 39, *Ferulago isaurica* (H) 26*, Heptaptera anatolica* (Fr) 24,
Heptacosane	*Heptaptera anatolica* (Fr) 23, *Heptaptera triquetra* (Fr) 23, *Heptaptera cilicica* (Fr) 11, *Heptaptera anisoptera* (Fr) 10, *Chaerophyllum aksekiense*

	(Fr) 10
1-Octadecanol	*Actinolema macrolema* (L) 24
Octanol	*Heracleum sphondylium* ssp. *ternatum* (Fr) 39-50, *Tordylium lanatum* (Fr) 22, *Tordylium apulum* (Fr) 17, *Tordylium pestalozzae* (Fr) 15, *Tordylium ketenoglui* (Fr) 12, *Tordylium trachycarpum* (Fr) 11, *Tordylium pustulosum* (Fr) 4-10

Table 34. Sesquiterpene hydrocarbons

β-Caryophyllene	*Bilacunaria aksekiensis* (Fr) 41, *Pimpinella corymbosa* (H) 38, (Fr) 14-33, (S+L) 33; *Bilacunaria boissieri* (H) 26, *Seseli libanotis* (H) 20, *Bupleurum pauciradiatum* (Fl) 10-18, *Tordylium aegypticum (*Fr) 11, *Bilacunaria anatolica* (Fr) 11, *Grammosciadium pterocarpum* (Fr) 11, (L) 10
Germacrene D	*Rhabdosciadium oligocarpum* (H) 62, *Prangos sp. nova* (Fr) 50*, Bupleurum heldreichii* (Fl) 48, (Fr) 48; *Smyrnium perfoliatum* (Fr) 9-47, *Bupleurum pauciradiatum* (Fl) 12-46, *Rhabdosciadium microcalycinum* (H) 25-33, *Thecocarpus carvifolius* (H) 31, *Aegokeras caespitosa* (Fr) 27-31, *Ferula anatolica* (Fr) 30, *Bupleurum intermedium* (Fr) 26, *Ferula duranii* (Fr) 25, *Trinia glauca* (Fr) 20, *Pimpinella rhodantha* (S+L) 17, *Seseli resinosum* (Fr) 14, *Ferula thirkeana* (Fr) 13-14, *Prangos heyniae* (Fr) 3-14, *Bupleurum croceum* (Fr) 13, *Pimpinella corymbosa* (S+L) 12, (Fr) 9, *Prangos turcica* (Fr) 11,
Germacrene B	*Prangos ferulacea* (Frcad) 30, *Actinolema macrolema* (Fr) 19-24, *Seseli gummiferum* ssp. *corymbosum* (H) 14, *Ferula elaeochytris* (Fr) 10, *Prangos heyniae* (Fr) 2-9
α-Humulene	*Cachrys alpina* (Fr) 33, *Neocryptodiscus papillaris* (Fr) 20*, Prangos pabularia* (Fr) 17, *Prangos turcica* (Fr) 11, *Pimpinella kotschyana* (Fr) 11, (S+L) 9, *Ferulago sandrasica* (Fr) 6, *Chaerophyllum aksekiense* (Fr) 7, *Tordylium syriacum* (Fr) 2-7
δ-Cadinene	*Kundmania anatolica* (Fr) 15, (H) 14, *Trinia glauca* (Fr) 13, *Ferula rigidula* (Fr) 6-13, *Ekimia bornmuelleri* (Fr) 11, *Seseli libanotis* (H) 9
Bicyclogermacrene	*Prangos pabularia* (Fr) 16*, Johrenia dichotoma* (Fr) 13, *Angelica purpurascens* (Fr) 12, *Seseli gummiferum* ssp. *corymbosum* (H) 12, *Pimpinella cappadocica* var. *cappadocica* (Fr) 12
α-Selinene	*Smyrnium perfoliatum* (Fr) 31
(*Z*)-β-Farnesene	*Scaligeria lazica* (Fr) 89, *Pimpinella tragium* ssp. *polyclada* (Fr) 57, (S+L) 23; *Grammosciadium pterocarpum* (Fr) 57, (L) 11*, Pimpinella rhodantha* (Fr) 35, (S+L) 13, *Scaligera tripartita* (S) 9, *Ferula tingitana* (Fr) 4
(*E*)-β-Farnesene	*Chaerophyllum aksekiense* (Fr) 6
Bicyclosesquiphellandrene	*Olymposciadium caespitosum* (Fr) *5*
β-Bisabolene	*Pimpinella tragium* ssp. *lithophila* (Fr) 30, *Pimpinella aurea (Fr) 33, Prangos heyniae* (Fr) 10-12
Selina-3,7(11)-diene	*Actinolema macrolema* (Fr) 12-15
γ-Guaiene	*Actinolema macrolema* (Fr) 11
1,4-Dimethylazulene	*Pimpinella aromatica* (R) 9
4,10-Dihydro-1,4-dimethylazulene	*Pimpinella aromatica* (R) 17, *Pimpinella tragium* ssp. *lithophila* (R) 14, *Pimpinella oliveiroides* (R) 6
4,6-Guaiadiene	*Ferulago syriaca* (Fr) 11, *Pimpinella tragium* ssp. *lithophila* (R) 7, (S+L) 0.3; *Pimpinella kotschyana* (S+L) 2, (Fr) 2, (R) 1; *Pimpinella corymbosa* (Fr) 1; *Pimpinella peregrina* (S+L) 0.1
7-Epi-1,2-dehydrosesquicineole (NEW)	*Ferulago uechtritzii* (Fr) 13
Dehydrosesquicineole	*Ferula orientalis* (H) 10
Geijerene	*Pimpinella affinis* (Fr) 59, (S+L) 40, (R) 36; *Scaligeria tripartita* (Fr) 55, (H) 37;

	Pimpinella tragium ssp. *lithophila* (S+L) 32, (R) 27, (Fr) 23;
Pregeijerene	*Pimpinella affinis* (Fr) 20, (S+L) 11, (R) 9; *Pimpinella tragium* ssp. *lithophila* (S+L) 8, *Scaligeria tripartita* (Fr) 6, (H) 5, *Pimpinella aromatica* (R) 5
Geijerene isomer	*Scaligeria tripartita* (Fr) 12, (H) 5
γ-Himachalene	*Pimpinella cappadocica* var. *cappadocica* (Fr) 9, *Pimpinella rhodantha* (Fr) 9
α-Zingiberene	*Pimpinella isaurica* (Fr) 16, *Pimpinella tragium* ssp. *pseudotragium* (Fr) 8
trans-β-bergamotene	*Pimpinella peregrina* (S+L) 70, (Fr) 41
Eremophilene	*Ferula halophila* (Fr) 5-9, *Ferula parva* (Fr) 9, *Ferula rigidula* (Fr) 3
Calarene	*Bupleurum sulphureum* (R) 27
Guaia-5,7(11)-diene	*Actinolema macrolema* (Fr) 37
Longipinene	*Szovitsia callicarpa* (Fr) 19

Table 35. Oxygenated sesquiterpenes

Caryophyllene oxide	*Kundmannia anatolica* (Fr) 31, (H) 19*, Pimpinella cappadocica* (Fr) 26, *Pimpinella corymbosa* (S+L) 17, (Fr) 11; *Bilacunaria anatolica* (H) 14, *Echinophora tournefortii* (H) 13, *Seseli libanotis* (H) 12, *Ferula lycia* (Fr) 3-10, *Tordylium aegyptiacum* (Fr) 9, *Bilacunaria boissieri* (H) 9, *Bilacunaria microcarpa* (H) 8, *Bilacunaria aksekiensis* (Fr) 8, *Ferulago aucheri* (Fr) 8, *Chaerophyllum aksekiense* (Fr) 6
Germacrene D-4-ol	*Ekimia bornmuelleri* (Fr) 43, *Ferula rigidula* (Fr) 8-10, *Prangos turcica* (Fr) 5
4α-Hydroxy germacra-1(10)-5-diene	*Seseli resinosum* (H) 30, (Fr) 22,
Isofuranogermacrene	*Smyrnium olusatrum* (R) 51, *Smyrnium perfoliatum* (R) 48, *Smyrnium rotundifolium* (Fr) 35-45
Furanodiene	*Smyrnium rotundifolium* (Fr) 28-39, *Smyrnium perfoliatum* (Fr) 20
Acetoxyfuranoeudesm-3-ene	*Smyrnium perfoliatum* (Fr) 9
β-Bisabolenal	*Prangos heyniae* (Fr) 18-53
β-Bisabolenol	*Prangos heyniae* (Fr) 2-15
Cubenol	*Ferulago mughlae* (Fr) 13, *Ferulago syriaca* (Fr) 9
Carotol	*Daucus carota* (Fr) 27-67, *Seseli andronakii* (Fr) 53, *Seseli petraeum* (H) 21
α-Cadinol	*Ekimia bornmuelleri* (Fr) 19, *Ferula rigidula* (Fr) 5-10, *Prangos* sp. *nova* (Fr) 9
(*E*)-Sesquilavandulol	*Seseli tortuosum* (Fr) 37, (H) 8; *Seseli campestre* (Fr) 3-12,
Humulene epoxide II	*Chaerophyllum aksekiense* (Fr) 8, *Ferulago aucheri* (Fr) 7
Spathulenol	*Seseli gummiferum ssp. gummiferum* (H) 20*, Bupleurum lancifolium* (Fl) 15, *Johrenia silenoides* (Fr) 15, (H) 13; *Bupleurum lycaonicum* (R) 14, *Seseli libanotis* (H) 12, *Prangos pabularia* (Fr) 11, *Ferulago aucheri* (Fr) 7, *Xanthogalum purpurascens* (Fr) 7, *Seseli gummiferum* ssp. *corymbosum* (H) 6, *Johrenia polyscias* (H) 6, *Johrenia dichotoma* (Fr) 5
Kessane	*Cnidium silaifolium* ssp. *orientale* (H) 33, *Xanthogalum purpurascens* (Fr) 7
Kessyl acetate	*Szovitsia callicarpa* (Fr) 65
1-Methyl-4-(6-methylhepta-1,5-dien-2-yl)-7-oxabicyclo[4.1.0] heptane ("**aureane**") (NEW)	*Pimpinella aurea* (Fr) 34, (S+L) 20, (R) 10*; Pimpinella peregrina* (S+L) 3, (Fr) 1, (R) 0.2*; Pimpinella tragium* ssp. *lithophila* (S+L) 0.2, (R) 0.2, (Fr) 0.1*; Pimpinella nudicaulis* (S+L) 0.1, (R) 0.1, (Fr) 0.02
4-(6-Methylbicyclo[4.1.0]hept-2-en-7-yl)butan-2-one ("**traginone**") (NEW)	*Pimpinella tragium ssp. lithophila* (S+L) 5, (Fr) 2, (R) 1*; Pimpinella affinis* (S+L) 5*,* (Fr) 1, (R) 0.6*; Pimpinella puberula* (R) 1, (S+L) 0.2*; Pimpinella tragium* ssp. *pseudotragium* (R) 1*, Pimpinella cappadocica* var. *cappadocica* (R) 0.1*, Pimpinella rhodantha* (R) 0.1
Dictamnol	*Pimpinella tragium* ssp. *lithophila* (S+L) 6, *Pimpinella affinis* (S+L) 4, (Fr) 2, (R) 1; *Pimpinella puberula* (R) 3, (S+L) 0.6; *Pimpinella tragium* ssp. *pseudotragium* (R) 0.6; *Pimpinella anisetum* (R) 0.5, (S+L) 0.2; *Pimpinella rhodantha* (S+L) 0.4, (R)

	0.2; *Pimpinella kotschyana* (R) 0.3, (S+L) 0.1, (Fr) 0.04; *Pimpinella peucedanifolia* (S+L) 0.3, *Pimpinella saxifraga* (R) 0.2, *Pimpinella cappadocica* var. *cappadocica* (R) 0.1,
Alismol	*Pimpinella rhodantha* (S+L) 1.4, (R) 1; *Pimpinella isaurica* (Fr) 0.4, *Pimpinella peucedanifolia* (Fr) 0.3
12-Hydroxy-β-caryophyllene acetate	*Pimpinella kotschyana* (Fr) 12, (S+L) 5, (R) 0.03; *Pimpinella corymbosa* (Fr) 5, (S+L) 3, (R) 0.04
Himachalol	*Pimpinella cappadocica* var. *cappadocica* (S+L) 16
Dehydrocostuslactone	*Pimpinella cappadocica* var. *cappadocica* (Fr) 8
Shyobunone	*Ferula drudeana* (Fr) 25-44
Epi-shyobunone	*Ferula drudeana* (Fr) 10-38
6-Epi-shyobunone	*Ferula drudeana* (Fr) 6-13
β-Eudesmol	*Ferula szowitsiana* (L) 32, (Stem) 30
α-Eudesmol	*Ferula szowitsiana* (L) 18, (Stem) 17
Methylfarnesoate	*Johrenia tortuosa* (Fr) 43, *Johrenia dichotoma* (Fr) 17, *Johrenia silenoides* (Fr) 9,
Muurola-4,10(14)-dien-1-ol	*Kundmannia anatolica* (Fr) 26, (H) 12
8-Cedren-13-ol	*Peucedanum longifolium* (H) 34

Table 36. Esters

Bornyl acetate	*Ferulago syriaca* (R) 69*, Bilacunaria macrocarpa* (H) 20, *Ferulago longistylis* (H) 13, (Fr) 4*;Ferula haussknechtii* (Fr) 7, *Prangos turcica* (Fr) 7, *Angelica sylvestris* var. *sylvestris* (S) 7*, Tordilium ketenoglu* (Fr) 7, *Prangos turcica* (Fr) 7, *Seseli campestre* (H) 5, *Ferula lycia* (H) 2,
Octyl acetate	*Heracleum paphlagonicum* (Fr) 27-95*, Heracleum crenatifolium* (Fr) 19-95, *Heracleum platytaenium* (Fr) 73-88, (H) 86, *Zosima absinthifolia* (Fr) 38, *Heracleum sphondylium* ssp. *ternatum* (Fr) 7-31, *Heracleum argeum* (Fr) 7
Octyl hexanoate	*Tordylium syriacum* (Fr) 46-81, *Tordylium hasselquistiae* (Fr) 73, *Tordylium pustulosum* (Fr) 69-73, *Tordylium lanatum* (Fr) 59, *Tordylium pestalozzae* (Fr) 56, *Tordylium apulum* (Fr) 44, *Zosima absinthifolia* (Fr) 32, *Heracleum platytaenium* (H) 13, (Fr) 3-5, *Heracleum argaeum* (Fr) 9, *Pastinaca sativa* ssp. *urens* (Fr) 5
Hexyl butyrate	*Heracleum argaeum* (Fr) 39, *Heracleum paphlagonicum* (Fr) 17-25
Hexyl hexanoate	*Malabaila secacul* (Fr) 73-86
Hexyl octanoate	*Malabaila secacul* (Fr) 9-14
Octyl butyrate	*Pastinaca sativa* ssp. *urens* (Fr) 80, *H. sphondylium* ssp. *ternatum* (Fr) 25-43, *Heracleum platytaenium* (Fr) 12-17
Octyl octanoate	*Tordylium trachycarpum* (Fr) 80, *Tordylium apulum* (Fr) 35, *Tordylium ketenoglui* (Fr) 29, *Tordylium pestalozzae* (Fr) 16, *Tordylium hasselquistiae* (Fr) 13, *Tordylium aegyptiacum* (Fr) 9
Octyl 2-methylbutyrate	*Tordylium pustulosum* (Fr) 18

Table 37. Others

Naphthalene	*Ferula szowitsiana* (Fr) 28, *Ferula lycia* (Fr) 3-27, *Ferula anatolica* (Fr) 22, *Ferula tingitana* (Fr) 14-15, *Ferula duranii* (Fr) 10, *Prangos turcica* (Fr) 9, *Ferula parva* (Fr) 5, *Ferula brevipedicellata* (Fr) 4, *Ferula communis* (Fr) 4
3,5-Nonadiyn-7-ene	*Prangos denticulata* (R) 20,
3,5-Nonadiyn-2-yl acetate	*Prangos platychlaena* ssp. *platychlaena* (Fr) 11-45,
3,5-Nonadiyn-2-yl acetate isomer	*Prangos platychlaena* ssp. *platychlaena* (Fr) 4
3,5-Nonadiyne	*Prangos platychlaena* ssp. *platychlaena* (Fr) 6-25,
Amylfuran	*Bupleurum falcatum* ssp. *cernuum* (R) 23

GENERAL REMARKS & CONCLUSIONS

1. In this paper, essential oil compositions of 179 Apiaceae taxa comprising 172 species of Turkey belonging to 53 genera were presented. The study covered at least 392 oil samples.
2. All the oils were obtained by standard procedures and analyzed by GC/MS techniques using commercial libraries as well as the home-made "*Baser Library of Essential Oil Constituents*" containing MS and retention data of over 4000 compounds.
3. Some Umbelliferae fruits were found particularly rich in essential oil, such as *Foeniculum vulgare* var. *vulgare* 6-12%, *Ferulago isaurica* (E) 12%, *Foeniculum vulgare* var. *piperitum* 4.3-7.7%, *Heracleum paphlagonicum* (E) 4.9-7.4%, *Ferulago trachycarpa* 7.3%, *Ferulago asparagifolia* 7.0%, *Laser trilobum* 5-7%, *Heracleum platytaenium* (E) 5.2-6.8%, *Ferulago longistylis* (E) 6.4%, *Pimpinella anisetum* (E) 5.0-5.3%, *Pimpinella aurea* 5.1%, *Pimpinella nudicaulis* 5.1%, *Ferulago syriaca* 4.8%, *Pimpinella anisum* 1.3-4.8%, *Pimpinella thirkeana* (E) 4.1%, *Ferulago humilis* (E) 3.9%, *Ferulago sandrasica* (E) 3.9%, *Ferula drudeana* (E) 3.7-3.8%, *Heracleum crenatifolium* (E) 3.7%, *Heracleum sphondylium* subsp. *ternatum* 3.7%, *Ferula elaeochytris* 3.5%, *Ferula duranii* (E) 2.6%, *Anethum graveolens* 2-2.5%, *Actinolema macrolema* 2.3%, *Ferula coskunii* (E) 2%, *Pimpinella cappadocica* (E) 2%, *Pimpinella flabellifolia* (E) 1.9%, *Ferula brevipedicellata* 1.9%. *Pimpinella aromatica* (Herba) 6.1%, (root) 4.2%.
4. Chemical diversity in the family Umbelliferae is evident.
5. Some genera such as *Pimpinella, Anthriscus, Foeniculum, Petroselinum, Scaligeria* are rich in phenylpropanoids and have commercial importance.

- *Cuminum cyminum, Laser trilobum, Bunium persicum* are rich in monoterpene aldehydes and possess similar odour properties, hence have commercial importance.
- *Lagoecia cuminoides, Peucedanum graminifolium, Trachyspermum copticum* are rich in thymol. Only the latter species is known in commerce. The former is the richest ever source of thymol (up to 95%). Oil yield of this common weed is over 1%. In some western parts of Turkey it is used as Herbaal tea. If cultivated it can become an important source of natural thymol.

6. Infraspecific diversity within a genus is also interesting. Essential oils may have chemotaxonomic significance. Some marker compounds are genus or species specific, e.g., compounds such as anethole and epoxypseudoisoeugenyl-2-methylbutyrate in *Pimpinella* and *Scaligeria*; furanosesquiterpenes in *Smyrnium*, shyobunones in *Ferula drudeana*, (+)-linalool in *Coriandrum sativum*.
7. It is quite frequent for Apiaceae plants to show different chemical profile in aboveground and underground organs of the same plant like in *Pimpinella peucedanifolia*: oils of fruits and leafy stems contain undecane as main constituent while root oil contains epoxypseudoisoeugenyl-2-methylbutyrate and 4-methoxy-2-(3-methyloxiranyl)-phenylisobutyrate.
8. Process conditions can be adjusted to obtain aromachemicals selectively from Umbelliferae fruits as shown in Cumin and Laser seed oils.
9. Taxonomic studies in the family Apiaceae are ongoing and the statuses of many genera are continuously modified. Table 38 gives a summary of our publications reporting essential oils of the species whose status have been modified

Table 38. New names of the species studied for essential oils

Old name	**New name**	**Reference**
Cachrys alpina M. Bieb.	*Prangos ilanae* Pimenov, Akalın & Kljuykov	Baser et al., 2004
Echinophora carvifolia Boiss. et Balansa	*Thecocarpus carvifolius* (Boiss.) Hedge & Lamond	Baser, Kurkcuoglu et al., 1998
Hippomarathrum boissieri Reut. & Hausskn. ex Boiss.	*Bilacunaria boissieri* (Boiss.) Pimenov & V.N.Tikhom.	Baser et al., 2000k
Hippomarathrum cristatum Boiss.	*Cachrys cristata* DC.	Ozek, G., et al 2007a
Hippomarathrum microcarpum (M.Bieb.) B.Fedtsch.	*Bilacunaria microcarpa* (M.Bieb.) Pimenov & V.N.Tikhom.	Ozer et al., 2007
Myrrhoides nodosa (L.) Cannon	*Physocaulis nodosus* (L.) Tausch	Tumen et al., 2005
Olymposciadium caespitosum (Sibth. & Sm.) H.Wolff	*Aegokeras caespitosa* (Sibth. & Sm.) Raf.	Kurkcuoglu & Baser Personal Comm..
Xanthogalum purpurascens Ave-Lall.	*Angelica purpurascens* (Ave-Lall.) Gilli	Ozek, G., et al., 2006b

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